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Flotation separation of bitumen from oil sand using ultrasound irradiation and mixed gases in aqueous solution

超音波照射と混合ガスを用いたオイルサンドからのビチューメン浮上分離

Tomonao Saito[1 ‡], Hirokazu Okawa[1], Youhei Kawamura[2], Tayfun Babadagli[3] ([1]Akita Univ.;[2]Curtin Univ.;[3]Univ. of Alberta)
斉藤知直 [1 ‡], 大川浩一 [1], 川村洋平 [2], Tayfun Babadagli[3] ([1]秋田大 ; [2]カーティン大 ; [3]アルバータ大)

1. Introduction

20 % of Canada's oil sand is located on the surface of the ground. These oil sands are taken by means of open-pit mining. About 10 % of oil sands consist of bitumen. Bitumen is used as fuel energy, and it is necessary to separate bitumen from oil sand at high efficiency. Main industrial processes to separate bitumen from oil sand are treatments using hot water (~100℃) and steam (>100℃) in rotating drums. These treatments consist of two processes. The first is the bitumen separation from oil sand and the second is the bitumen flotation from aqueous solution to the solution surface. The use of ultrasound irradiation (20-40 kHz) for bitumen separation has been investigated to improve the yield of bitumen and to reduce the energy of recovery process (1-3). The use of air bubbles for the rising of bitumen to the solution surface has been reported as an effective flotation method (4).

In this study, we investigated the optimal combination of ultrasound and gases to improve the separation efficiency and the yield of bitumen from oil sand in the hot water process.

2. Experimental Methods

2.1 Bitumen separation

The experimental apparatus is shown in Fig.1. Sonication was performed using an ultrasonic generator and a submersible transducer (28 kHz). The output of this device was adjusted to 200W. A flat bottomed flask was used as a reactor. Solution temperature in the flask was controlled by a circulation system.

A sample of oil sand from Alberta, Canada was used in this experiment. The sample size of the oil sand was 3-5mm (Fig.2). A suspension was prepared by mixing oil sand (2.97g) and sodium hydroxide (0.03 g) with distilled water (60ml) in a flask. Before the treatment by sonication, the suspension was subjected to a gas flow of air, argon (Ar) or carbon dioxide (CO_2) at 100 ml/min for 30 min. Then the suspensions were treated using sonication for 15 min at 85℃. After the treatment, the separated bitumen floating on the surface was collected and weighed after drying. The oil sand and recovered bitumen were analyzed with a thermo-gravimetric analyzer (TGA, TG-8120; Rigaku) under Ar flow. The TGA spectra were acquired in the temperature ranging from 30 to 800℃ with the heating rate of 10 ℃ min^{-1}. Experiments at individual conditions were conducted twice.

2.2 Bitumen flotation

A suspension was prepared by mixing bitumen (0.5 g) and sodium hydroxide (0.03 g) with distilled water (60 ml) in a flask. Before the treatment by sonication, the suspension was subjected to a gas flow of air, Ar or CO_2 at 100 ml/mi for 30 min. Then the suspensions were treated either with ultrasound irradiation or without it for 15 min at 85℃. After the treatment, the floating bitumen on the water surface was collected and weighted after drying .

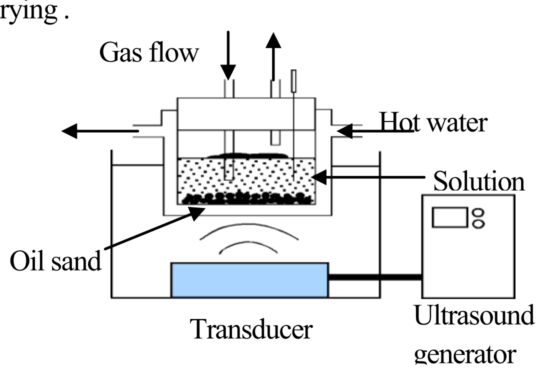

Fig.1 Schematic design of the experimental apparatus.

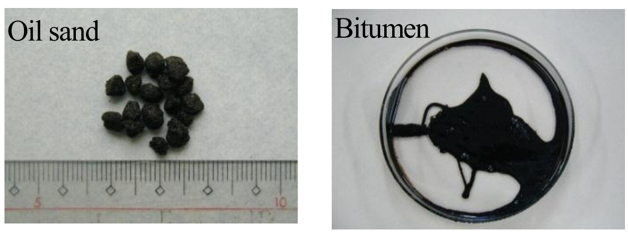

Fig.2 Photographs of oil sand and bitumen.

3. Results and Discussion

3.1 Bitumen Recovery Quantification

Analysis of the sample of oil sand by a TGA indicated that the bitumen weight percentage was 12.3wt%. This percentage was nearly the same as the reported bitumen weight percentage in the oil sand [4].

In this study, the bitumen recovery from oil sand was quantified by a following formula. The mass of bitumen-sand rising to the water surface (M) by the treatment is the total of the bitumen mass itself (M_b) and the mass of the entrapped sand grains (M_s); $M = M_b + M_S$. The recovery rate of bitumen (%) = M_b / 0.123 $M_0 \times 100$. Purity=M_b / M. The mass of the oil sand added to the solution is M_0. TGA was used to measure the weight of M_b.

3.2 Bitumen separation

Figure 3 shows the results of the recovery rate of bitumen from oil sand using ultrasound irradiation for 15 min under various atmospheres. The amount of bitumen recovery rate was 23.0% in air, 38.2% in Ar and 39.8% in CO_2. The purity of bitumen was 0.87 in air, 0.89 in Ar and 0.68 in CO_2. These results show that Ar was effective in the recovery of bitumen during sonication.

In CO_2 condition, the vesicles were generated at the surface of oil sand. The vesicles made the oil sand rise more easily to the surface of the solution. However, saturated vapor pressure of CO_2 is lower than those of other gases. Therefore, the number of cavities generated by ultrasound irradiation is lower than those of other gases, leading to a decrease in the effect of bitumen separation.

3.2 Bitumen flotation

Figure 4 shows the results of the recovery rate of bitumen with or without ultrasound irradiation for 15 min under various atmospheres. Without ultrasound, the amount of bitumen recovery was 9.85 % in CO_2. With ultrasound, the recovery rate increased to 26.0 % in CO_2. The bitumen recovery rates in air and Ar conditions were 0 % regardless of ultrasound irradiation. CO_2 gases attached to the bitumen surface, thus can effectively float bitumen to the solution surface. CO_2 solubility in water is higher than the other gases (air: 0.87, Ar: 1.52, CO_2:38.9[$\times 10^{-3}$ mol/l]). When the solution was irradiated by ultrasound, the dissolved gas appeared as bubbles. A large number of bubbles attached on the bitumen surface contributed to the low specific gravity of bitumen.

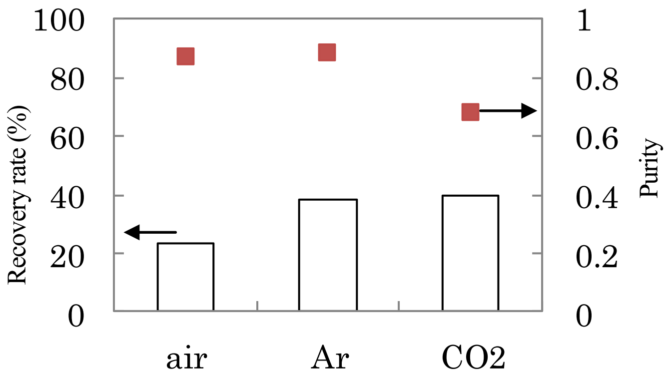

Fig.3 Recovery rate and purity of bitumen from oil sand using sonication for 15 min at 85°C under various atmospheres.

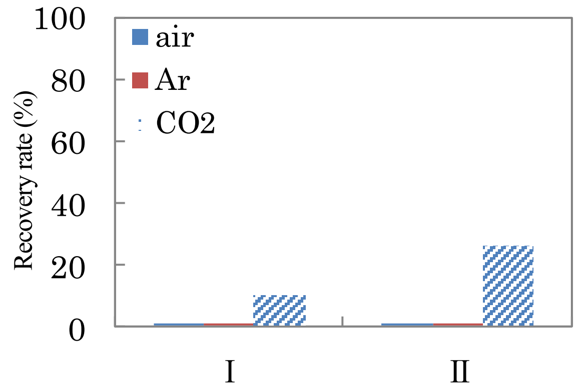

Fig.4 Recovery rate of bitumen using sonication for 15 min at 85°C under various atmospheres.
(I: without ultrasound, II: with ultrasound)

4. Conclusions

We found that the Ar gas was effective in the recovery of bitumen during sonication whereas CO_2 gas was effective for the floatation of bitumen.

In the future, we will examine the flotation separation of bitumen from oil sand using ultrasound irradiation and mixed gases (Ar and CO_2) in aqueous solution.

References

(1) O.V. Abramov, V.O. Abramov, S.K. Myasnikov, and M.S. Mullakaev: Ultrasonics Sonochem. **16** (2009) 408

(2) K.M. Sadeghi, J.R. Lin, and T.F. Yen: Energy Sources **16** (1994) 439

(3) H. Okawa, T. Saito, R. Hosokawa, T. Nakamura, Y. Kawamura, and S. Koda: Jpn. J. Apple. Phys. **50** (2011) 07HE12

(4) Jacob H, Masliyah., et al., *Handbook on Theory and Practice of Bitumen Recovery from Athabasca Oil sands.* Canada: Kingsley Knowledge Publishing, 2011