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Enhancement of bitumen recovery from oil sand in alkaline solution using ultrasound and carbon dioxide

超音波と CO_2 を用いたアルカリ溶液中におけるオイルサンドからのビチューメン増進回収

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1. Introduction

Canada has vast crude bitumen resources and the amount of proven reserve is 77.4 billion barrels.[1)] Bitumen, heavy oil, can be recovered from oil sands which are mixture of bitumen, sand (quartz) and water.[2)] The bitumen content of oil sands is about 10 wt%. Crude bitumen has very high viscosity and high density at room temperature. Therefore, it is difficult to recover bitumen from oil sands at low tempeature. Normally, bitumen is recovered from oil sands by hot water-based bitumen extraction treatment including bitumen liberation and bitumen aeration. Bitumen liberation is the separation of bitumen from sand grains. Hot water reduces viscosity. Alkaline solution, which can decrease interfacial tension of bitumen and sand, is used to separate bitumen easily from sand grains. After bitumen liberation, aeration is necessary to collect bitumen droplets which remain in the suspended solution at surface of the solution. However, alkaline solution, especially above pH9, is a less favorable condition for bitumen aeration. Air bubble is difficult to attach bitumen because the surface becomes more hydrophilic. Therefore, contact angle of bitumen-air bubble becomes low. Novel ideas are needed to perform bitumen aeration efficiently in alkaline solution.

In this study, we investigated the combination of ultrasound and carbon dioxide (CO_2) gas to improve the aeration efficiency in the water-based bitumen treatment. We also performed bitumen recovery using ultrasound and CO_2 gas, and investigated the yield of bitumen from oil sand in the hot water process.

2. Experiment

2.1 Bitumen aeration

A suspension, bitumen dispersed solution, was prepared as the following steps. Sodium hydroxide solution (pH13, 60 ml) was prepared using sodium hydroxide and ion-exchanged water. CO_2 gas was injected into the solution to remove dissolved air for 20 min at 100 mL/min. After the CO_2 injection, pH was adjusted at 13 using sodium hydroxide solution (10 M). Bitumen (0.5 g) was added into the solution and irradiated by ultrasound (38 kHz) for 15 min (**Fig. 1**). The suspension was used for bitumen aeration test. Then the suspension was treated with ultrasound irradiation for 5 min under CO_2 gas flow at 20mL/min at 15ºC. During the treatment, we maintained the pH value at 13 by dropping the certain amount of NaOH solution (10 M). We collected the bitumen on the surface of the solution and measured the recovery amount of bitumen.

2.2 Bitumen recovery from oil sand

A sample of oil sand from Alberta, Canada was used and the size is 3–5 mm. A suspension was prepared by mixing oil sand (2.97 g) and sodium hydroxide (0.03 g) with distilled water (60 mL) in a flask. Before the treatment using ultrasound, argon (Ar) gas was injected to the solution at 100 ml/min for 30 min. Sonication was performed using an ultrasonic generator and a submersible transducer (28 kHz). The output of this device was adjusted to 200 W. A flat-bottomed flask was used as a reactor. Solution temperature in the flask was controlled by a circulation system. Then the suspensions were treated using sonication for 15 min at 85 °C with Ar gas flow at 100 ml/min. After the treatment, ultrasound was irradiated again with CO_2 gas injection into the solution at 100 ml/min to enhance floatation of bitumen for 15 min. The floating bitumen on the surface was collected and weighed after drying.

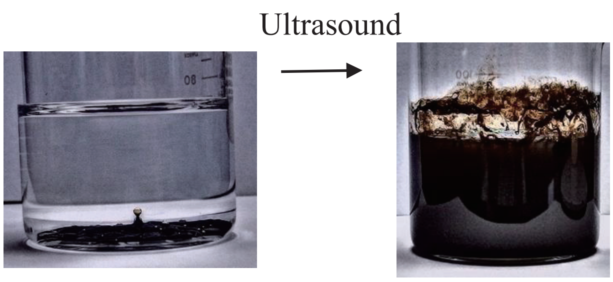

Fig. 1 Appearance of bitumen suspension prepared by ultrasound irradiation of the solution including bitumen and NaOH at 15 ºC for 15 min.

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3. Results and discussion

3.1 Bitumen aeration

Figure 2 shows results of recovery ratios of bitumen aerated by CO_2 or air gas at 20 ml/min for 15 min with/without ultrasound irradiation. In air condition, the amount of bitumen recovery was less than 20%. On the other hand, combination of ultrasound and CO_2 showed high recovery rate of 58.6%. From the difference of recovery ratios with and without ultrasound irradiation, ultrasound enhanced bitumen recovery ratio. One of the reasons is that ultrasound has possibility to increase the collision number between bitumen droplets and air or CO_2 gas bubbles. When CO_2 gas used, the bitumen recovery ratio became higher than air condition. We investigated the reason by contact angle measurement. Bitumen was spread on glass plate. The glass plate was set on the bottom of watch glass including NaOH solution (pH11–13). Air or CO_2 bubbles were put on bitumen of the plate. Contact angle, Θ, was illustrated in **Fig. 3**. Contact angle of air bubble-bitumen was 72.6º at pH11.1 (**Fig. 4a**) and this value is almost same with the value reported by Zhou.[3] Contact angle of CO_2 bubble-bitumen showed very high value of 89.9º at pH12.6 (**Fig. 4b**). Therefore, CO_2 can show high bitumen recovery ratio in strong alkaline solution of pH13.

2.2 Bitumen recovery from oil sand

Oil sand sample used in this study was included the bitumen of 12.3 wt%. **Figure 5** shows the bitumen recovery ratios from oil sand using ultrasound irradiation for 15 min under Ar gas flow at 100 mL/min to enhance bitumen liberation followed by ultrasound irradiation again for 15 min under Ar or CO_2 gas flow at 100 mL/min to enhance bitumen floatation. The bitumen recovery ratio was 49.6% using Ar, and 86.5 % using combination of Ar and CO_2. These results show that combination utilization of Ar and CO_2 gas is effective to separate bitumen from oil sand and float bitumen on the surface of solution.

Acknowledgment

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References

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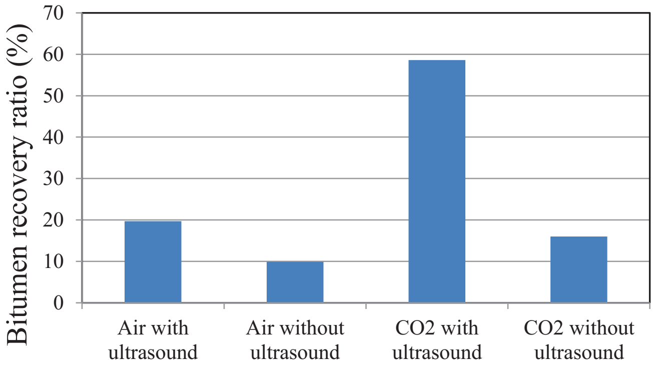

Fig. 2 Bitumen recovery ratio using aeration of CO_2 or air gas at 20 mL/min for 15 min with/without ultrasound in alkaline solution of pH13.

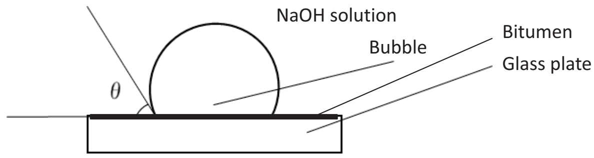

Fig. 3 Schematic illustration of contact angle of gas bubble on bitumen.

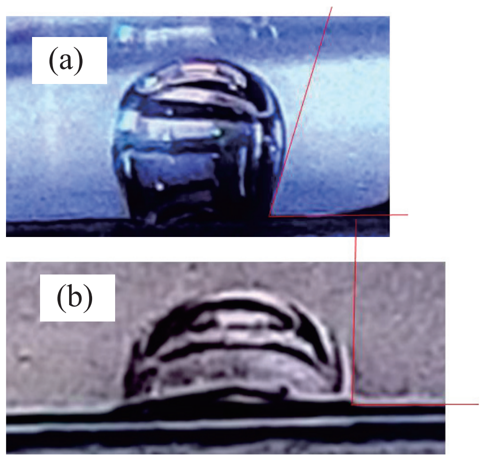

Fig. 4 Contact angle of air (a) or CO_2 (b) bubble on bitumen.

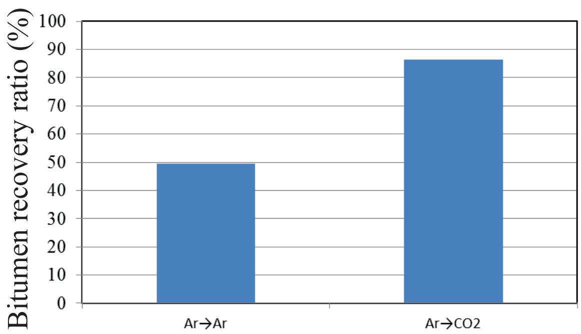

Fig. 5 Bitumen recovery ratio from oil sand by 2 times ultrasound treatments using Ar or CO_2 gas at 100 mL/min (total treatment time = 30 min).