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The Effect of Bitumen Extraction Shear Conditions on Froth Treatment Performance

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EXTENDED ABSTRACT

Introduction

One of the goals in oil sands development is to process poorer quality oil sands while reducing energy consumption. To achieve this goal, it is necessary to optimize the two main stages of oil sands processing: extraction and froth treatment. The most common extraction process is hot water bitumen extraction where bitumen is produced in a froth consisting of bitumen, water, and inorganic solids. The froth is treated in a second stage to separate the bitumen. There are currently two commercialized froth treatment processes in Alberta, here termed the "Syncrude Process" and the "Albian Process". In the Syncrude process, the froth is diluted with naphtha to decrease the density and viscosity of the bitumen and to promote coalescence of emulsified water. Phase separation is achieved with centrifuging. The Albian process, a paraffinic solvent is added to the froth to reduce the bitumen density and viscosity, and to promote flocculation of the emulsified water and suspended solids. Some asphaltenes are also precipitated to achieve a product suitable for a conventional refinery. Phase separation is achieved with gravity settling.

In both processes, it is desirable to reduce energy costs and minimize the water and solids content of the product bitumen. In the past, research has aimed to optimize each stage in isolation. Now we are seeking to establish the relationship between bitumen extraction conditions and froth treatment effectiveness for different quality oil sands. Hence, the optimization of the overall process can be evaluated. In this work, the effect of shear conditions during bitumen extraction is considered. Overall bitumen recovery and the water and solids content of the product bitumen are determined for a low shear and a high shear extraction process.

EXPERIMENTAL

A high quality (HQOS) and a low quality (LQOS) oil sand samples were obtained from Syncrude Canada Ltd. The bitumen, water, and solids contents were determined at the Syncrude Research Centre, as reported elsewhere[1], and are given in Table 1. Oil sand quality is assessed in terms of bitumen and fine solids content. Poorer quality oil sand froths have lower oil content and higher contents of water and solids.

Table 1. Oil sands composition

Oil Sand	Bitumen, wt%	Water, wt%	Solids, wt%	Fines (<44μm)* wt%
HQOS	14.3	1.2	84.4	4.1
LQOS	6.6	7.3	86.1	34.0

**Fraction of fines in solids.*

Bitumen extractions were performed using a Batch Extraction Unit (BEU) or a Denver Cell (DC) following the Syncrude standard extraction procedures[1]. The BEU is a low-shear laboratory approximation of the Clark hot water extraction process and typically produces a froth similar to that obtained from the traditional commercial process with conditioning and separation stages. The DC is a higher shear flotation apparatus and produces a froth that is more similar to that obtained from a commercial process with hydrotransport and separation stages. Extractions were performed at 50 and 80°C and sodium hydroxide was added to improve the bitumen recovery. Subsamples of froth from the extractions were collected and assayed for oil, water and solid contents using the "Syncrude method"[2,3]. Only primary froth was used for froth treatment experiments.

Two froth treatments were considered: 1) dilution with toluene followed by centrifuging, Aromatic Solvent (AS) Method; 2) dilution with heptane followed by gravity settling, Paraffinic Solvent (PS) Method [2,3]. The AS Method is an approximation of the Syncrude process while the PS Method is an approximation of the Albian Process. Note that toluene is used for the AS Method while naphtha is used for the Syncrude process. Also, the PS Method is a single-stage separation while the Albian process is a three-stage separation. Process temperatures of 23 and 60°C were evaluated for both methods. Separations were evaluated after 5 minutes and 8 hours for the AS Method and after 40 minutes and 8 hours of settling for the PS Method.

For both methods, the volumes of the phases were determined at the specified times. The water content of the continuous oil phase was measured with Karl Fischer analysis. For AS Method, a material balance was performed to confirm that the measured volumes and compositions were consistent with the original froth analysis. Images of the different phases were obtained using a Zeiss Axiovert S100 optical microscope.

RESULTS AND DISCUSSION

For BEU extractions without caustic, bitumen recovery was found to decrease as the quality of the oil sand decreased[3]. However, the bitumen recovery during extraction could be maximized at an optimum amount of NaOH addition. No NaOH was required to optimize recovery for the HQOS. The optimum NaOH level for the LQOS is 0.15 wt% for both BEU and DC at 50°C and 0.1 wt% for BEU at 80°C. The optimum level of NaOH for the LQOS has yet to be verified for DC at 80°C.

Table 2 compares extraction bitumen recovery and froth composition for extractions performed on HQOS using the BEU and the DC (50 and 80°C, no caustic and 0.05 wt% NaOH). The higher shear in the DC leads to higher bitumen recovery but also higher water and solids content in the froth. Note that there is only a single stage of froth recovery for the DC while there are two stages (primary and secondary recovery) for the BEU.

Table 2. Bitumen extraction data

Extraction Unit / Oil Sand	Primary Bit.Rec. (wt%)	Secondary Bit.Rec. (wt%)	Primary Froth Composition (wt%) Oil	Water	Solids
80°C, no NaOH					
BEU/HQOS	84.1	13.9	68.1	19.7	12.2
BEU/LQOS	24.3	10.46	27.5	40.2	32.3
DC/LQOS	43.3	-	14.6	46.4	39.0
50°C, 0.05 wt%NaOH					
BEU/LQOS	48.1	28.0	57.5	33.0	9.5
DC/LQOS	96.6	-	33.8	49.3	16.9

Figure 1 compares the water contents in the product bitumen separated from HQOS and LQOS using the AS Method and 5 minutes of separation. The froths were extracted by using the BEU at 80°C without caustic. In general, the water content in oil phase decreases as the toluene-to-bitumen ratio increases. A better separation is achieved as the diluted bitumen viscosity decreases and the density difference between water and the diluted bitumen increases. The water content at a given toluene-to-bitumen ratio is much higher for LQOS than for HQOS probably because the fines content is much higher. The fines likely inhibit coalescence, preventing the formation of larger, more easily separated droplets.

Figure 2 shows the water contents in the product bitumen produced from LQOS for BEU and DC-froths using the AS Method and 5 minutes of separation. The water content at a given toluene-bitumen ratio is higher for DC-froth. It is likely that the larger fines content of the DC-froth reduces the effectiveness of the froth treatment. Therefore, higher solvent ratios are required to treat the DC-froth.

Figure 3 shows the water contents in the product bitumen produced using the PS Method for froth produced with BEU (HQOS) and with both BEU and DC (LQOS). The bitumen extraction was performed at 80°C without NaOH. For HQOS froth, zero water in bitumen can be obtained at about 1.2 wt/wt heptane-to-bitumen ratio. This ratio corresponds to the onset of asphaltene precipitation[2,3]. It is likely that flocculation of the water, solids, and precipitated asphaltenes drives the separation. For LQOS froth from the BEU with no NaOH, the optimum heptane-to-bitumen ratios are much higher. It is possible that the higher fines content inhibits coalescence or flocculation. Despite the higher fines content in the DC froth, there is no significant difference between the froth treatment performance for the BEU and DC froths when using the PS Method.

ACKNOWLEDGEMENTS

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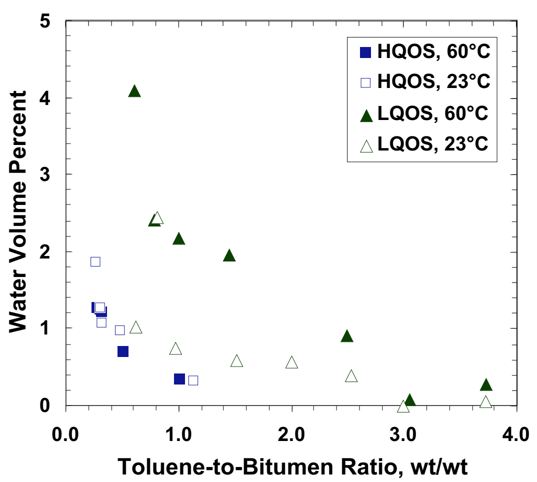

Figure 1. Water content in bitumen produced with AS Method (5 min.) at different toluene-to-bitumen ratios from HQOS and LQOS (BEU, 80°C, no NaOH addition).

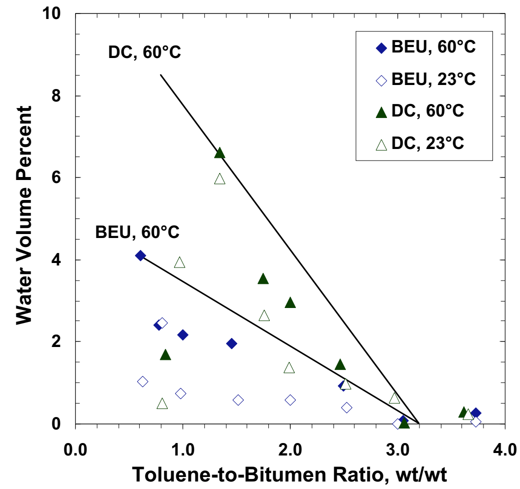

Figure 2. Water content in bitumen produced with AS Method (5 min.) at different toluene-to-bitumen ratios from LQOS (BEU and DC, 80°C, no NaOH addition).

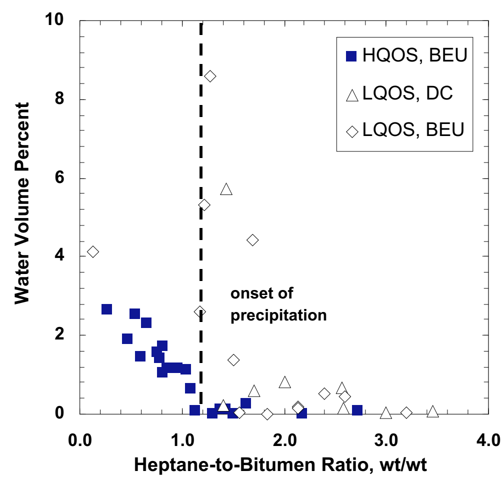

Figure 3. Water content in bitumen produced with PS Method (23°C, 8 hrs) at different heptane-to-bitumen ratios from HQOS and LQOS (extraction at 80°C, no NaOH addition).

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