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Towards the Improvement of the Efficiency of Oil Sands Froth Treatment

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EXTENDED ABSTRACT

INTRODUCTION

Over fifteen million cubic meters per annum of synthetic crude are produced in Alberta from the mined oil sands. The production is projected to increase to nearly one million barrels per day by 2011[(1)]. As high quality ore deposits are depleted, it will be necessary to process poorer quality ores; that is ores with less bitumen and more fines. At the same time, it is desirable to reduce the process energy requirements.

There are two main stages to 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. Poorer quality oil sand froths have lower oil content and higher contents of water and solids[(2)].

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 has been tested at the pilot scale and the commercial process is now under construction. In this 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. The two froth treatment processes are investigated in this work using laboratory scale approximations. The goal is to identify the optimum solvent-to-bitumen ratios and temperatures for the effective treatment of froth produced from oil sands of various qualities. The effective of the treatment is assessed in terms of bitumen recovery and the water content of the bitumen product.

EXPERIMENTAL

Oil sand samples of three different qualities were obtained from Syncrude Canada Ltd. (Table 1). The bitumen, water, and solids contents as were determined at the Syncrude Research Centre as reported elsewhere[(3)]. According to these parameters, the oil sands are termed low- (LQOS), average- (AQOS) and high-quality ores (HQOS) Bitumen froth was extracted from the oil sand using a batch extraction unit (BEU) at 80°C and following the Syncrude standard extraction procedure[(3)].

Subsamples of froth from the batch extractions were collected and assayed for oil, water and solid contents using the "Syncrude method"[(3)]. Only primary froth was used for froth treatment experiments because of the low amount of secondary froth.

For bitumen extraction from HQOS and AQOS, no chemicals were used. For LQOS, sodium hydroxide was used. The maximum bitumen recovery of almost 100% was achieved with the addition of approximately 0.025 wt% NaOH (on an oil sand basis). The effect of NaOH addition during extraction was also investigated for the low quality oil sand froth. Different NaOH levels from 0 to 0.125 wt% were considered.

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. Process temperatures of 23 and 60 °C were evaluated for both methods.

With the AS Method, a sample of froth was placed in a test tube and preheated toluene was added to a desired toluene-to-bitumen (T/B) ratio. The mixture was centrifuged for 5 minutes at 4000 rpm and then allowed to equilibrate in a temperature bath at the desired temperature for 2 hours. Cycles of centrifuging and settling were repeated for up to eight hours. To represent short residence times, the diluted froth was analyzed after 5 minutes of centrifuging and before any equilibration. To represent the ultimate forth treatment performance, the diluted froth was analyzed after 8 hours of treatment.

Note that the AS Method is not exactly comparable to the Syncrude process because toluene is an aromatic solvent while naphtha is a mixture of naphthenes and paraffins. Toluene was chosen for practical reasons and because the viscosity and density of toluene are similar to naphtha. However, while bitumen is soluble in both naphtha and toluene, the solubility of asphaltenes is lower in naphtha than toluene and hence there may be differences in the performance of the AS Method compared with the commercial process.

With the PS Method, the froth was diluted with n-heptane of the room temperature to a desired heptane-to-bitumen (H/B) ratio. The solution was allowed to gravity settle in a temperature bath at the desired temperature. To represent short and ultimate residence times, the diluted froth was analyzed after 40 minutes and 8 hours of settling, respectively. Note that the PS Method is a single stage process while the Albian Process is multistage.

For both methods, the volumes of the phases were determined both during the experiments and after. The water content of the continuous oil phase was measured with Karl Fischer analysis. A material balance was performed to confirm that the measured volumes and compositions were consistent with the original froth analysis.

RESULTS AND DISCUSSION

AS Method: For the AS Method, almost 100 % bitumen recovery can be achieved at both 23 and 60°C and at 5 minute and 8 hour residence times (Table 2) for all oil sands; that is, all of the bitumen reported to the oil phase.

In general, the water content decreases exponentially as the T/B ratio increases (Figure 1). When the optimum T/B ratio is achieved, further dilution typically achieves little or no reduction in the water content. There is some scatter in the water contents at high dilution but they typically are less that 0.5 wt%. Bitumen viscosity is a key factor in the process. Therefore, higher solvent-to-bitumen ratios are required at lower temperatures.

The presence of fines appears to hinder settling and therefore higher solvent-to-bitumen ratios are required for lower quality oil sands. The addition of NaOH in the extraction stage does not appear to impact the froth treatment.

PS Method: For the PS Method, bitumen recoveries of 75-90% can be achieved without caustic at the optimum H/B ratios (Table 3). Recovery at the optimum H/B ratio appears to be independent of temperature and residence time at least above 40 minutes. Lower residence times were not assessed because insufficient settling had occurred. Bitumen recovery does depend on the ore quality and decreases when the quality of ore decreases. Higher recoveries can be expected in the commercial multistage process.

The water content decreases sharply when the optimum H/B ratio is achieved (Figure 2) implying that a different treatment mechanism is at work compared to the AS Method. The emulsified water droplets in the froth are typically coated with asphaltenes. Addition of the paraffinic solvent (n-heptane) leads to the flocculation of these droplets together with the inorganic solids. Hence, the proximity to the onset of asphaltene precipitation is a key factor in the process. As a result, the optimum solvent-to-bitumen ratios are nearly independent of temperature.

The presence of fines appears to hinder settling and therefore significantly higher solvent-to-bitumen ratios are required for lower quality oil sands.

The addition of NaOH in the extraction stage strongly impacts the froth treatment. The optimum H/B ratios for bitumen extracted from LQOS with the addition of NaOH are given in Table 4. Lower H/B ratios are required to achieve an effective separation than were required when NaOH was not present. Also, when the froth contains NaOH, bitumen recovery increases to above 90% at the optimum H/B ratio. Addition of NaOH below the optimum level for extraction, decreases the effectiveness of the froth treatment.

ACKNOWLEDGEMENTS

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2. Kasperski, K. Review of Research on Aqueous Extraction of Bitumen from Mined Oil Sands, CANMET Division Report CWRC 01-17 (CF), 2001, 162 p.
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Table 1. Oil sands composition

Oil sand quality	Bitumen, wt%	Water, wt%	Solids, wt%	Fines (<44μm)*, wt%
High	14.3	1.2	84.4	4.1
Average	11.8	1.3	86.6	5.2
Low	8.6	5.3	86.1	35.4

**Fraction of fines in solids.*

Table 2. Optimum toluene-to-bitumen ratios for the AS Method (no NaOH addition in extraction)

Oil sand Quality	Optimum T/B ratio (wt/wt)			
	60°C, 8 hr	60°C, 5 min	23°C, 8 hr	23°C, 5 min
High	0.75±0.1	0.75±0.1	1.00±0.1	1.00±0.1
Average	0.80±0.1	0.80±.0.1	1.10±0.1	1.10±0.1
Low	0.50±0.1	1.25±0.2	0.50±0.1	1.25±0.2

Table 3. Optimum heptane-to-bitumen ratios for the PS Method (no NaOH addition in extraction)

Oil sand quality	Optimum H/B ratio (wt/wt)			
	60°C, 8 hr	60°C, 40 min	23°C, 8 hr	23°C, 40 min
High	1.10±0.1	1.10±0.1	1.10±0.1	1.00±0.1
Average	1.15±0.1	1.75±.0.1	1.15±0.1	1.75±0.1
Low	1.75±0.1	1.75±0.2	1.75±0.1	1.75±0.2

Table 4. Optimum heptane-to-bitumen ratios for low-quality oil sand for the PS Method (NaOH addition in extraction)

NaOH addition, wt%	Optimum H/B ratio (wt/wt)			
	60°C, 8 hr	60°C, 40 min	23°C, 8 hr	23°C, 40 min
0.013	1.20±0.1	1.50±0.2	1.30±0.1	1.70±0.1
0.025	0.60±0.2	1.60±.0.1	1.60±0.1	1.75±0.1
0.050	0.75±0.1	1.50±0.2	1.40±0.2	1.50±0.1
0.125	1.00±0.1.	1.10±0.1	1.10±0.1	1.10±0.1

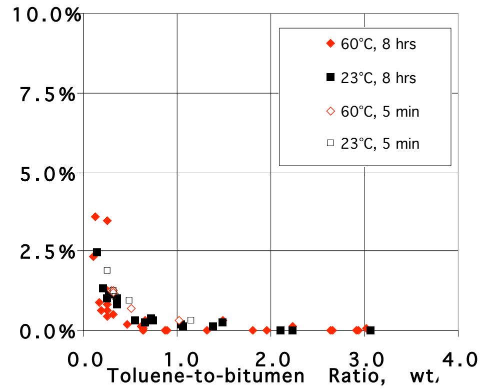

Figure 1. Water content of oil phase produced with AS Method at different toluene-to-bitumen ratios from high quality oil sand froth (no NaOH addition in extraction)

ONSET OF PRECIPITATION

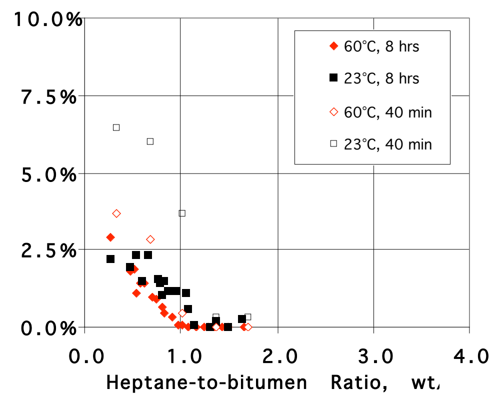

Figure 2. Water content of oil phase produced with PS Method at different heptane-to-bitumen ratios from high quality oil sand froth (no NaOH addition in extraction).