PROCESS SAFETY AND ENVIRONMENT PROTECTION 86 (2008) 268–276

Contents lists available at ScienceDirect

Process Safety and Environment Protection

journal homepage: www.elsevier.com/locate/psep

Filterability of oil sands tailings

Yuming Xu[a,*], *Tadek Dabros*[a], *Jianmin Kan*[b]

[a] *CANMET Energy Technology Centre-Devon, Natural Resources Canada, Devon, Alberta, Canada T9G 1A8*
[b] *TOTAL E&P Canada, Suite 19000, 333 7th Avenue SW, Calgary, Alberta, Canada T2P 2Z1*

ABSTRACT

In Canadian oil sands mining operations, bitumen is extracted from oil sands using the hot water extraction process, which produces tremendous amounts of tailings. Currently, these tailings are disposed of in large ponds, in which coarse particles settle out relatively quickly and fine particles remain suspended in water and settle very slowly. After years of settling, the fine particles form a stable suspension in water known as mature fine tailings (MFTs). Long-term storage of the MFT is costly and poses a major environmental liability.

Oil sands companies are now actively investigating different approaches to replace or reduce the use of oil sands tailings ponds. Filtration of the tailings to produce "dry tailings" for stacking is now being investigated as an alternative by a number of companies. Fast water drainage is a critical step for the filtration process. In this paper, we use simple laboratory-scale filtration tests to evaluate the filterability of the oil sands tailings and to generate a parameter that can be used in filtration scale-up. It was found that the filterability of the original coarse oil sands tailings was relatively low. However, after the fines are flocculated with the coarse particles to form uniform flocs the filterability was improved by several orders of magnitude. The results demonstrate that filtration of the flocculated coarse tailings to produce the "dry" stackable tailings may be viable.

Keywords: Oil sands tailings; Filterability; Specific resistance to filtration; Tailings disposal; Flocculation

1. Introduction

The oil sands reserves in Northern Alberta, Canada are playing an increasingly important role in maintaining the oil supply for Canada and North America. It has been estimated that there are about 1.7 trillion barrels of bitumen in these deposits (Alberta Energy, 2002). The oil sands typically contain about 10 wt% of heavy hydrocarbons known as bitumen. In open-pit operations, the oil sands ore is removed through surface mining and the bitumen is separated from sand grains by the hot water extraction process, in which the oil sands ore is mixed with hot water – with (or without) the addition of caustic – and bitumen is separated as froth from a flotation process (Shaw et al., 1996). This oil sands extraction process produces huge amounts of tailings; more than 3 m^3 of tailings are generated for every barrel of bitumen produced. In the current commercial plants, the freshly produced fine tailings from the extraction operation are pumped to large settling ponds. The coarse solids settle out quickly as sand beach while the fine particles settle very slowly and, after many years of settling, form a stable suspension containing about 30 wt% solids, known in the industry as mature fine tailings (MFTs). Over the years, large volumes of MFT have been accumulated in the ponds. For example, in one of the commercial oil sands plants, about 380 million cubic meters of MFT had been accumulated up to 1999 and some of the MFT had to be pumped to the mined-out pit for long-term storage (Cymerman et al., 1999). The continuing accumulation of MFT is causing great economical and environmental concerns.

Significant efforts have been devoted to finding alternatives to tailings ponds. In the last decade, a number of bench-scale and pilot-scale tests were conducted to implement paste technology. In this approach, synthetic polymers were used to flocculate the fines (defined as solid particles smaller than 44 μm in size) to produce paste-like material (Cymerman et al., 1999; Lord and Liu, 1998; Matthews et al., 2003; Regensburg and Lord, 2000; Xu and Cymerman, 1999; Xu and Hamza, 2003; Xu et al., 2004). It was proposed that the paste be stored in the pit to allow further drainage of the water, thereby producing a dry deposit, or that it be disposed of with the sand.

* *Corresponding author*.
E-mail address: yxu@nrcan.gc.ca (Y. Xu).
Received 21 December 2007; Accepted 2 April 2008
0957-5820/$ – see front matter
doi:10.1016/j.psep.2008.04.005

Nomenclature

a	intercept from the plot of t/V versus V
A	filter area (m^2)
b	slope from the plot of t/V versus V
L_m	the fictitious equivalent thickness of the filter medium (kg/m^2)
P	the pressure applied on the top of the filter cake (Pa)
r	specific resistance to filtration of the filter cake (m/kg)
s	compressibility coefficient of filter cake
t	filtration time (s)
V	the volume of the filtrate (m^3)
w	the fractional solids content per unit volume of filtrate liquid, or the mass of solids cake formed per unit filtrate volume passing through (kg/m^3)

Greek letter

μ	viscosity of filtrate (Pa s)

In order to find other alternatives to current methods of tailings disposal, oil sands companies are investigating for methods of dry and stackable tailings disposal. This is becoming more urgent for new oil sands mines due to increasing regulatory restrictions on building new tailings ponds and limits on pond space. Another important consideration for dry tailings disposal is related to water shortage. Water consumption is becoming a more serious issue, and therefore, maximizing the water recovery from tailings brings great benefit.

One of the methods for achieving dry tailings is filtration. Filtration is one of the most traditional methods for solid–liquid separation. It has been widely used in other industries. In the mid-1990s, pilot-scale tests were conducted on a different bitumen extraction process known to Alberta's oil sands industry as the *Bitmin Process* (Sury and Stone, 1995). In these tests, filtration of coarse oil sands tailings was also evaluated. However, due to the extremely large volume of tailings to be processed and lack of pressure and incentive in implementing dry tailings disposal, the filtration has never been implemented. However, recently, it has been considered as an option for tailings disposal by several oil sands companies.

In order to investigate the feasibility of oil sands tailings filtration, we conducted a series of bench-scale filtration tests. The objective of this study was to investigate the filterability of the tailings and the effect of various factors, such as tailings composition (fines content) and flocculant addition, on filtration performance. The data generated will provide a useful reference for future pilot-scale tests and commercial implementation of the filtration technique.

2. Methods and materials

2.1. *Filtration equations*

The filtration tests were conducted using a bench-scale pressure filtration unit. The filtration pressure was constant through the entire filtration period. Filtration models have been widely used in industry. Detailed derivation of the filtration equations can be found in many publications or chemical engineering text books (Cao and Jahazi, 2005; Earle and Earle, 1983, 2004; McCabe et al., 1975). During the filtration, the flow rate of the filtrate depends on pressure difference across the filter cake and the resistance from the filter medium and the filter cake. The volumetric flow rate of the filtrate can be described by the following equation

$$\frac{dV}{dt} = \frac{AP}{\mu r w V/A + \mu r L_m} \qquad (1)$$

V: the volume of the filtrate (m^3), A: the filter area (m^2), P: the pressure applied on the top of the filter cake (Pa), μ: the viscosity of filtrate (Pa s), w: the fractional solids content per unit volume of filtrate liquid, or the mass of solids cake formed per unit filtrate volume passing through (kg/m^3), r: the specific resistance of the filter cake (m/kg), and L_m: the fictitious equivalent thickness of the filter medium (kg/m^2).

In the denominator on the right side of Eq. (1), the first term represents the resistance from the filter cake and the second term represents the resistance from the filter medium.

At constant pressure, integration of Eq. (1) leads to the filtration equation:

$$\frac{t}{V} = \frac{\mu r w}{2PA^2} V + \frac{\mu r L_m}{PA} \qquad (2)$$

Eq. (2) indicates that a plot of t/V versus V would give a straight line with the intercept a and slope b:

$$a = \frac{\mu r L_m}{PA} \qquad (3)$$

$$b = \frac{\mu r w}{2PA^2} \qquad (4)$$

where a has the unit of s/m^3 and b has the unit of s/m^6,

Eq. (2) can then be rewritten as

$$\frac{t}{V} = a + bV \qquad (5)$$

The specific resistance to filtration, r, and the equivalent thickness of the filter medium, L_m, can be calculated from the slope and intercept through Eqs. (6) and (7)

$$r = \frac{2PA^2}{\mu w} b \qquad (6)$$

$$L_m = \frac{aw}{2Ab} \qquad (7)$$

The specific resistance to filtration measures the filterability of the slurry as determined by the characteristics of the slurry. For the incompressible cake the specific resistance to filtration is independent of the pressure. This parameter has been used to assess the filterability and the filtration rate in other industries such as mining and waste treatment (Baskerville et al., 1971; Gale and Baskerville, 1970; Lockyear and Stevenson, 1986; Smollen, 1986). It was reported that the time required to achieve a cake is directly proportional to the specific resistance to filtration for the filter press operation (Baskerville et al., 1971). For the vacuum filter the yield is inversely proportional to the square root of the specific resistance (Gale and Baskerville, 1970). More than 10 years ago this parameter was introduced to the oil sands industry by Xu et al. as one of the index tests for characterization of oil sands tailings (Hamza, 1995).