



(51) International Patent Classification:

C02F 1/34 (2006.01) *C02F 1/38* (2006.01)
B01F 11/00 (2006.01) *C02F 1/56* (2006.01)
C02F 11/14 (2006.01) *C02F 11/12* (2006.01)
C10G 1/04 (2006.01) *C02F 103/10* (2006.01)

(21) International Application Number:

PCT/US2017/042569

(22) International Filing Date:

18 July 2017 (18.07.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/366,206 25 July 2016 (25.07.2016) US

(71) Applicant: DOW GLOBAL TECHNOLOGIES LLC
[US/US]; 2040 Dow Center, Midland, MI 48674 (US).

(72) Inventors: MOHLER, Carol E.; 1712 Building, Washington Street, Midland, MI 48674 (US). POINDEXTER, Michael K.; 2301 N. Brazosport Blvd., Freeport, TX 77541 (US). SANDERS, Thomas L.; 1712 Bldg, Washington

Street, Midland, MI 48674 (US). WITHAM, Cole A.; 2301 N. Brazosport Blvd., Freeport, TX 77541 (US).

(74) Agent: CHRISTY, M.; The Dow Chemical Company, Intellectual Property, P.O. Box 1967, Midland, Michigan 48641-1967 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

(54) Title: ACOUSTIC MIXING FOR FLOCCULANT ADDITION TO MINERAL SUSPENSIONS

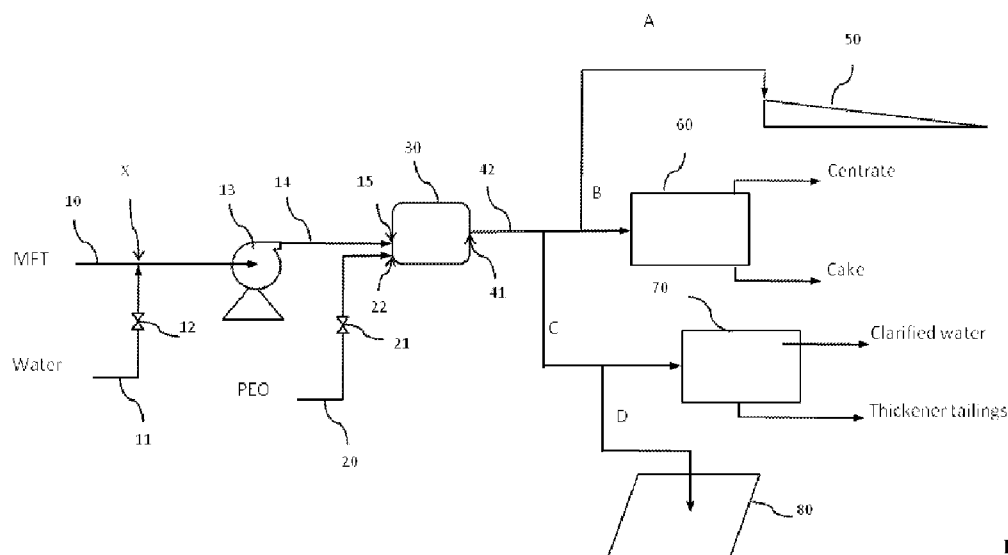


Fig. 1

(57) Abstract: The present invention relates to a process for mixing a flocculant composition with mineral suspensions, especially waste mineral slurries, using an acoustic mixer. Preferably the flocculant composition is a polymeric flocculant composition preferably comprising a poly(ethylene oxide) homopolymer or copolymer. The process of the present invention is particularly suitable for the treatment of tailings and other waste material resulting from mineral processing, in particular, processing of oil sands tailings.



EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ACOUSTIC MIXING FOR FLOCCULANT ADDITION TO MINERAL SUSPENSIONS

FIELD OF THE INVENTION

5 The present invention relates to a process for mixing a flocculant composition with mineral suspensions, especially waste mineral slurries, using an acoustic mixer. The flocculant composition is a polymeric flocculant composition preferably comprising a poly(ethylene oxide) homopolymer or copolymer. The process of the present invention is particularly suitable for the treatment of tailings and other waste material resulting from
10 mineral processing, in particular, processing of oil sands tailings.

BACKGROUND OF THE INVENTION

Fluid tailings streams derived from mining operations, such as oil sands mining
15 operations, are typically composed of water and solid particles. In order to recover the water and consolidate the solids, solid/liquid separation techniques must be applied. In oil sands processing a typical fresh tailings stream comprises water, sand, silt, clay and residual bitumen. Oil sands tailings typically comprise a substantial amount of fine particles (which are defined as solids that are less than 44 microns).

20 The bitumen extraction process utilizes hot water and chemical additives such as sodium hydroxide or sodium citrate to remove the bitumen from the ore body. The side effect of these chemical additives is that they can change the inherent water chemistry. The inorganic solids as well as the residual bitumen in the aqueous phase acquire a negative charge. Due to strong electrostatic repulsion, the fine particles form a stabilized suspension
25 that does not readily settle by gravity, even after a considerable amount of time. In fact, if the suspension is left alone for 3-5 years, a gel-like layer known as mature fine tailings (MFT) will be formed and this type of tailings is very difficult to consolidate further even with current technologies.

Recent methods for dewatering MFT are disclosed in WO 2011/032258 and WO
30 2001/032253, which describe in-line addition of a flocculant solution, such as a polyacrylamide (PAM), into the flow of oil sands tailings, through a conduit such as a

pipeline. Once the flocculant is dispersed into the oil sands tailings, the flocculant and tailings continue to mix as they travel through the pipeline and the dispersed fine clays, silt, and sand bind together (flocculate) to form larger structures (flocs) that can be separated from the water when ultimately deposited in a deposition area. However, the degree of
5 mixing and shearing is dependent upon the flow rate of the materials through the pipeline as well as the length and diameter of the pipeline. Thus, any changes in the fluid properties or flow rate of the oil sands fine tailings may have an effect on both mixing and shearing and ultimately flocculation. Thus, if one has a length of open pipe, it can be difficult to control flocculation because of the difficulty in independently controlling both the shear rate and
10 residence time simply by changing the flow rate.

CA Patent Application No. 2,512,324 suggests addition of water-soluble polymers to oil sands fine tailings during the transfer of the tailings as a fluid to a deposition area, for example, while the tailings are being transferred through a pipeline or conduit to a deposition site. However, once again, proper mixing of polymer flocculant with tailings is
15 difficult to control due to changes in the flow rate and fluid properties of the tailings material through the pipeline.

US Publication No. 2013/0075340 discloses a process for flocculating and dewatering oil sands tailings comprising adding oil sands tailings as an aqueous slurry to a stirred tank reactor; adding an effective amount of a polymeric flocculant, such as charged
20 or uncharged polyacrylamides, to the stirred tank reactor containing the oil sands tailings, dynamically mixing the flocculant and oil sands tailings for a period of time sufficient to form a gel-like structure; subjecting the gel-like structure to shear conditions in the stirred tank reactor for a period of time sufficient to break down the gel-like structure to form flocs and release water; and removing the flocculated oil sands fine tailings from the stirred tank
25 reactor when the maximum yield stress of the flocculated oil sands fine tailings begins to decline but before the capillary suction time of the flocculated oil sands fine tailings begins to substantially increase from its lowest point.

While polyacrylamides are generally useful for fast consolidation of tailings solids, they are highly dose sensitive towards the flocculation of fine particles, and it is challenging
30 to find conditions under which a large proportion of the fine particles are flocculated. As a result, the water recovered from a PAM consolidation process is often of poor quality and

may not be good enough for recycling because of high fines content in the water.

Additionally, tailings treated with PAM are shear sensitive so transportation of treated thickened tailings to a dedicated disposal area (DDA) and general materials handling can

become a further challenge. Alternatively, polyethylene oxide (PEO) is known as a

5 flocculant for mine tailings capable of producing a lower turbidity supernatant as compared to PAM, for example see USP 4,931,190; 5,104,551; 6,383,282; WO 2011070218; Sharma, S.K., Scheiner, B.J., and Smelley, A.G., (1992). Dewatering of Alaska Pacer Effluent Using PEO. *United States Department of the Interior, Bureau of Mines*, Report of Investigation 9442; and Sworska, A., Laskowski, J.S., and Cymerman, G. (2000). Flocculation of the
10 Syncrude Fine Tailings Part II. Effect of Hydrodynamic Conditions. *Int. J. Miner. Process.*, 60, pp. 153-161. However, PEO homopolymers and copolymers have not found widespread commercial use in oil sands tailing treatment because of mixing and processing challenges resulting from its high viscosities with clay-based slurries.

In spite of the numerous processes and polymeric flocculating agents used therein,
15 there is still a need for a flocculating process to further improve the settling and consolidation of suspensions of materials as well as further improve upon the dewatering of suspensions of waste solids that have been transferred as a fluid or slurry to a settling area for disposal. In particular, it would be desirable to provide a more effective treatment of waste suspensions, such as oil sands tailings, transferred to disposal areas ensuring
20 improved concentration of solids and improved clarity of released water with improved shear stability and wider dose tolerance.

BRIEF SUMMARY OF THE INVENTION

25 The present invention is a process for flocculating and dewatering a mineral suspension, preferably an aqueous suspension of oil sands tailings, comprising the steps: i) providing a mineral suspension to an acoustic mixer, ii) providing a flocculant composition to said acoustic mixer, preferably the flocculant is added to the mineral suspension before, during, or after addition to the acoustic mixer, and iii) acoustically mixing the mineral
30 suspension and the flocculant composition to provide a flocculated mineral suspension.

One embodiment of the process of the present invention described herein above further comprises the step: ii) a) providing a coagulant to said acoustic mixer.

One embodiment of the process of the present invention described herein above further comprises the step: iv) adding the conditioned flocculated oil sands fine tailings to
5 at least one centrifuge to dewater the flocculated oil sands fine tailings and form a high solids cake and a low solids centrate.

Another embodiment of the process of the present invention described herein above further comprises the step: v) adding the conditioned flocculated oil sands fine tailings to a thickener to dewater the flocculated oil sands fine tailings and produce thickened oil sands
10 fine tailings and clarified water.

Another embodiment of the process of the present invention described herein above further comprises the step: vi) adding the conditioned flocculated oil sands fine tailings to at least one deposition cell such as an accelerated dewatering cell for dewatering.

Another embodiment of the process of the present invention described herein above further comprises the step: vii) spreading the conditioned flocculated oil sands fine tailings
15 as a thin layer onto a sloped deposition site.

In one embodiment of the process of the present invention disclosed herein above, the flocculant composition comprises one or more of a polyacrylate, a polymethacrylate, a polyacrylamide, a partially-hydrolyzed polyacrylamide, a poly(ethylene oxide)
20 homopolymer, a poly(ethylene oxide) copolymer, a cationic derivatives of polyacrylamide, a polydiallyldimethylammonium chloride (pDADMAC), a copolymer of DADMAC, a cellulosic material, a chitosan, a sulfonated polystyrene, a linear and/or branched polyethyleneimine, a polyvinylamine, a polyalkylene glycol, a polyquat/hyalauronic acid, a polyacrylic, a polyacrylamide(acrylic acid) copolymer, a poly(acrylamide-co-diallyl
25 dimethylammonium chloride), guar, a hydrophobically alkali-soluble emulsion, an alkali-swellable emulsion, a hydrophobically modified ethoxylated urethane polymer, or mixtures thereof.

In one embodiment of the process of the present invention disclosed herein above, the poly(ethylene oxide) polymer is a poly(ethylene oxide) copolymer of ethylene oxide
30 with one or more of epichlorohydrin, propylene oxide, butylene oxide, styrene oxide, an epoxy functionalized hydrophobic monomer, glycidyl ether functionalized hydrophobic

monomer, a silane-functionalized glycidyl ether monomer, or a siloxane-functionalized glycidyl ether monomer.

In one embodiment of the process of the present invention disclosed herein above, the poly(ethylene oxide) (co)polymer has a molecular weight of equal to or greater than
5 1,000,000 Da, preferably 8,000,000 Da.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of embodiments A to D of the process of the present invention.

10

DETAILED DESCRIPTION OF THE INVENTION

According to the present invention, we provide a process for dewatering a mineral suspension comprising acoustically mixing the suspension with a flocculating composition.
15 Typically, the material to be flocculated is a mineral suspension and may be derived from or contain filter cake, industrial tailings, thickener underflows, legacy tailings (sometimes called mature fine tailings), fluid fine tailings, fine tailings, froth tailings, flotation tailings, or unthickened plant waste streams, for instance other mineral tailings, slurries, or slimes, including phosphate, diamond, gold slimes, mineral sands, tails from zinc, lead, copper,
20 silver, uranium, nickel, iron ore processing, coal, oil sands or red mud. The material may be solids settled from the final thickener or wash stage of a mineral processing operation. Thus the material desirably results from a mineral processing operation. Preferably the material comprises tailings. Preferably the mineral material would be selected from red mud and tailings containing clay, such as oil sands tailings, etc.

25 The oil sands tailings or other mineral suspensions may have a solids content in the range 5 percent to 80 percent by weight. The slurries or suspensions often have a solids content in the range of 10 percent to 70 percent by weight, for instance 25 percent to 40 percent by weight. The sizes of particles in a typical sample of the fine tailings are substantially all less than 45 microns, for instance about 95 percent by weight of material is
30 particles less than 20 microns and about 75 percent is less than 10 microns. The coarse tailings are substantially greater than 45 microns, for instance about 85 percent is greater

than 100 microns but generally less than 10,000 microns. The fine tailings and coarse tailings may be present or combined together in any convenient ratio provided that the material remains pumpable.

The dispersed particulate solids may have a unimodal, bimodal, or multimodal
5 distribution of particle sizes. The distribution will generally have a fine fraction and a coarse fraction, in which the fine fraction peak is substantially less than 44 microns and the coarse (or non-fine) fraction peak is substantially greater than 44 microns.

The flocculating composition of the present invention comprises one or more flocculant selected from polyacrylates, polymethacrylates, polyacrylamides, partially-
10 hydrolyzed polyacrylamides, poly(ethylene oxide) homopolymers, poly(ethylene oxide) copolymers, cationic derivatives of polyacrylamides, polydiallyldimethylammonium chloride (pDADMAC), copolymers of DADMAC, cellulosic materials, chitosan, sulfonated polystyrene, linear and branched polyethyleneimines, polyvinylamines, polyalkylene glycols, polyquat/hyalauronic acids, polyacrylics, polyacrylamide(acrylic acid) copolymers,
15 poly(acrylamide-co-diallyl dimethylammonium chloride), guar, hydrophobically alkali-soluble emulsions, alkali-swellaable emulsions, hydrophobically modified ethoxylated urethane polymers, or mixtures thereof. A preferable flocculant comprises a poly(ethylene oxide) homopolymer, a poly(ethylene oxide) copolymer, or mixtures thereof, herein after collectively referred to as "poly(ethylene oxide) (co)polymer".

20 A suitable amount of the flocculant to be added to the mineral suspensions range from 10 grams to 10,000 grams per ton of dry mineral solids. Generally the appropriate dose can vary according to the particular material and material solids content. Preferred doses are in the range 30 to 7,500 grams per ton, more preferably 100 to 3,000 grams per ton, while even more preferred doses are in the range of from 500 to 3,000 grams per ton.
25 The flocculant composition may be added to the suspension of particulate mineral material, e.g., the tailings slurry, in solid particulate form, an aqueous solution that has been prepared by dissolving and/or suspending the flocculant into water, or an aqueous-based medium, or a suspended slurry in a solvent.

The flocculant composition of the process of the present invention comprises,
30 consists essentially of, or consists of a polymeric flocculant, preferably poly(ethylene oxide) homopolymer, a poly(ethylene oxide) copolymer, or mixtures thereof. Poly(ethylene)oxide

(co)polymers and methods to make said polymers are known, for example see WO 2013116027.

Suitable poly(ethylene oxide) homopolymers and poly(ethylene oxide) copolymers useful in the method of the present invention have a weight average molecular weight equal to or greater than 100,000 daltons (Da) and equal to or less than 15,000,000 Da, preferably
5 equal to or greater than 1,000,000 Da and equal to or less than 8,000,000 Da.

Poly(ethylene oxide) (co)polymers are particularly suitable for use in the method of the present invention as flocculation agents for suspensions of particulate material, especially waste mineral slurries. Poly(ethylene oxide) (co)polymers are particularly suitable
10 for the method of the present invention to treat tailings and other waste material resulting from mineral processing, in particular, processing of oil sands tailings.

In the process of the present invention, the flocculant composition comprising a poly(ethylene oxide) (co)polymer may further comprise, consist essentially of, or consist of one or more other types of flocculant (e.g., polyacrylates, polymethacrylates, polyacrylamides, partially-hydrolyzed polyacrylamides, cationic derivatives of
15 polyacrylamides, polydiallyldimethylammonium chloride (pDADMAC), copolymers of DADMAC, cellulosic materials, chitosan, sulfonated polystyrene, linear and/or branched polyethyleneimines, polyvinylamines, etc.) or other type of additive typical for flocculant compositions.

For example, an additive typical for flocculant compositions is a coagulant. Suitable
20 coagulants are salts of calcium (e.g., gypsum, calcium oxide, and calcium hydroxide), aluminum (e.g., aluminum chloride, sodium aluminate, and aluminum sulfate), iron (e.g., ferric sulfate, ferrous sulfate, ferric chloride, and ferric chloride sulfate), magnesium (e.g., magnesium chloride or magnesium carbonate), other multi-valent cations and pre-
25 hydrolyzed inorganic coagulants, may also be used in conjunction with the flocculant composition, preferably with a poly(ethylene oxide) (co)polymer.

In one embodiment, the present invention relates to a process for dewatering oil sands tailings. As used herein, the term "tailings" means tailings derived from oil sands extraction operations and containing a fines fraction. The term is meant to include fluid fine
30 tailings (FFT) and/or mature fine tailings (MFT) tailings from ongoing extraction operations (for example, thickener underflow or froth treatment tailings) which may bypass a tailings

pond and from tailings ponds. The oil sands tailings will generally have a solids content of 10 to 70 weight percent, or more generally from 25 to 40 weight percent, and may be diluted to 20 to 25 weight percent with water for use in the present process.

Acoustic-Mixing Process and Machine:

5 The process of the present invention comprises the step of acoustically mixing a flocculant, preferably a polymeric flocculant, more preferably a poly(ethylene oxide) (co)polymer with a mineral suspension or mineral slurries. The process of the present invention is particularly suitable for the treatment of tailings and other waste material resulting from mineral processing, in particular, processing of oil sands tailings.

10 Acoustic mixing introduces acoustic energy into liquids, slurries, powders and pastes. "Acoustic mixer" is a term used to describe a broad-based machine that causes acoustic oscillations.

 The underlying principle of operations for an acoustic-mixing machine include the use of mechanical energy from an electrical or hydraulic motor to rotate an eccentric drive
15 assembly that is coupled to a mechanical member e.g., one or more bars or plates, weights, or springs. Some common members are a specially treated solid steel bar and a hollow tube resonator (HTR). The rotational frequency of the oscillator is adjusted to bring this mechanical member into resonance and the energy is then acoustically transferred to the material to be mixed.

20 Acoustic mixing is distinct from conventional impeller agitation found in a planetary mixer or speed mixer as well as ultrasonic mixing. Low frequency, high-intensity acoustic energy is used to create a uniform shear field throughout the entire mixing vessel. The result is rapid fluidization (like a fluidized bed) and dispersion of material.

 Acoustic mixing differs from ultrasonic mixing in that the frequency of acoustic
25 energy is orders of magnitude lower. As a result, the scale of mixing is larger. Unlike impeller agitation, which mixes by inducing bulk flow, the mixing occurs on a microscale throughout the mixing volume.

 Issues that may arise with the use of conventional mixers that possess impellers include, but are not limited to, a moderate mixing cycle (longer time to accomplish mixing);
30 limited high-viscosity mixing capability; viscous heating; limited filler loading capability; high shear localized mixing; it requires contact mixing, and thus impeller cleaning is an

additional step that must be utilized in the process; and the process includes mixing and transferring to a container, followed by shipping.

To the contrary, advantages to be found by using an acoustic mixer include, but are not limited to, fast mixing cycle; excellent high-viscosity mixing capability; low heat
5 generation; high rate of filler loading; high intensity mixing throughout the volume of material to be mixed; non-contact, hygienic, sealed mixing; and a shorter process.

The selected acoustic mixer in accordance with the present invention provides intimate mixing by applying a consistent shear field throughout the entire vessel, and thus may be especially suitable for the mixing of viscous polymers, solids, powders, or materials
10 of dissimilar viscosities.

Suitable acoustic mixers are within the purview of those skilled in the art. In one embodiment of the process of the present invention, the acoustic mixer may include a closed vessel without impellers, which uses low-frequency, high intensity acoustic energy to provide the desired mixing.

15 A suitable acoustic mixer for use in accordance with the present disclosure includes LABRAM™ mixers, without impellers, commercially available from Resodyn Acoustic Mixers, Inc. (Butte, Mont.) The acoustic mixer is operated at a resonant frequency. A closely controlled electromechanical oscillator is used to excite the mix material. The acoustic mixer may operate at a frequency of from about 10 Hertz to about 200 Hertz,
20 preferably from about 30 Hertz to about 100 Hertz. The entire system may oscillate in resonance, allowing highly efficient energy transfer and rapid mixing of the components of the mixture.

Preferably, a suitable acoustic mixer may handle polymer solutions with a viscosity up to about 100 million centipoise (cP), preferably from about 1 cP to about 80 million cP.
25 Compared with an impeller-based mixer, an acoustic mixer can easily achieve good mixing within a very short time, in embodiments from 5 seconds to 300 minutes, in other embodiments from 30 seconds to 60 minutes.

In one embodiment of the process of the present invention, the flocculant composition is introduced to the aqueous MFT in the acoustic mixer as an aqueous mixture.

In one embodiment of the process of the present invention, the flocculant and MFT compositions come into contact before they enter the acoustic mixer, at the point they both enter the acoustic mixer, or after they have each entered the acoustic mixer.

In another embodiment of the process of the present invention, the flocculant
5 composition is introduced directly to the aqueous MFT in the acoustic mixer in its neat form (i.e., as a powder, a paste, a liquid, etc.).

In one embodiment the process of the present invention is a batch process.

In another embodiment the process of the present invention is a continuous process.

A schematic of four embodiments, A, B, C and D, of the present invention is shown
10 in **FIG. 1**. In one embodiment, a mineral suspension, for example, an aqueous suspension of oil sands mature fine tailings (MFT) in line **10** are pumped via pump **13** through a transportation conduit, preferably a first pipeline, line **14**. If desired, additional water can be added to the MFT through line **11** at Point **X**. The MFT enters the acoustic mixer **30** through mixer inlet pipes **15**. In one embodiment (shown in **FIG. 1**), the flocculant
15 composition, for example comprising a poly(ethylene oxide) (co)polymer (referred herein after to as “PEO”), is added to the acoustic mixer **30** as an aqueous mixture through line **20** at mixer inlet pipe **22**. In another embodiment (not shown in **FIG. 1**) the flocculant composition is added neat directly to the acoustic mixer **30** as a powder. In yet another embodiment (not shown in **FIG. 1**) an additional additive, such as a coagulant, is added to
20 acoustic mixer **30** before or during mixing.

The process of the present invention is conducted in an acoustic mixer **30** located between a first pipe **14** in which material enters the acoustic mixer **30** and a second pipe **42** in which material exits the acoustic mixer **30**. Once material has exited the acoustic mixer **30** it may be further conditioned, treated and/or deposited in a sloped deposition area.
25 Generally, the line **14** which enters the acoustic mixer **30** is the same (i.e., the same diameter) as the line **42** which leaves the acoustic mixer **30**, however the line **14** which enters the acoustic mixer **30** may have a larger diameter than line **42** which leaves the acoustic mixer **30**, or the line **14** which enters the acoustic mixer **30** may have a smaller diameter than line **42** which leaves the acoustic mixer **30**. Typical industrial tailings
30 pipeline **14** diameters are in the range from 8 inches to 36 inches.

After leaving the in-line acoustic mixer **30** the acoustically mixed solution of MFT and PEO comprising floc exits through line **42**. In one embodiment, once the acoustically mixed solution of MFT and PEO leaves the acoustic mixer **30** through line **42** it is allowed to continue to build floc, sometimes referred to as conditioning, before deposition or further treatment.

Line **42** may comprise a static mixer, a small tank, an enlarged diameter section of piping, or a length of pipe with or without bends to create a favorable hydrodynamic environment for conditioning the fluid mixture. Preferably conditioning is allowed to take place for at least 5 seconds, preferably at least 10 seconds, preferably at least 15 seconds, more preferably at least 20 seconds, more preferably at least 30 seconds, and more preferably at least 45 seconds. The upper time limit for conditioning is whatever is practical for the particular process, but typically, an adequate time for conditioning is equal to or less than an hour, equal to or less than 30 minutes, more preferably equal to or less than 10 minutes, more preferably equal to or less than 5 minutes more preferably less than 1 minute.

Preferably, in the process of the present invention, there is a concentration of solids to at least 45 weight percent after 20 hours from a starting MFT solution of 30 weight percent solids. Preferably there is continued thickening with an increase of solids to 50 weight percent or more over a timeframe of 100 to 1000 hours.

In one embodiment of the process of the present invention (**A**) shown in **FIG. 1**, the flocculated MFT is transported to a thin lift sloped deposition site **50** having a slope of 1 percent to 4 percent to allow water drainage. This water drainage allows the material to dry at a more rapid rate and reach trafficability levels sooner. Additional layers can be added and allowed to drain accordingly.

In another embodiment of the process of the present invention (**B**) shown in **FIG. 1**, the flocculated MFT is transferred via line **17** to a centrifuge **60**. A centrifuge cake solid containing the majority of the fines and a relatively clear centrate having low solids concentrations are formed in the centrifuge **60**. The centrifuge cake can then be transported, for example, by trucks or pipelines, and deposited in a drying cell.

In a further embodiment of the process of the present invention (**C**) shown in **FIG. 1**, the flocculated MFT is transported and placed in a thickener **70**, said thickener **70** may

comprise rakes (not shown in **FIG. 1**), to produce clarified water and thickened tailings for further transport and disposal.

Yet a further embodiment of the process of the present invention (**D**) is shown in **FIG. 1**, the flocculated MFT is deposited at a controlled rate into a dewatering cell **80**, for example a tailings pit, basin, dam, culvert, or pond, or the like which acts as a fluid containment structure. The subsequent rate of dewatering of the treated tailings can be enhanced using accelerated dewatering techniques. The containment structure may be filled with flocculated MFT continuously or the treated MFT can be deposited in layers of varying thickness. The water released may be removed using pumps (not shown in **FIG. 1**)

followed by additional placement of acoustically and chemically treated tailings. The deposit fill rate is such that maximum water is released during or just after deposition. Preferably, the deposited particulate mineral material will reach a substantially dry state. In addition the particulate mineral material will typically be suitably consolidated and firm e.g., due to simultaneous settling and dewatering to enable the land to bear significant weight.

The present invention provides improved methods of mixing that more efficiently combine the flocculant and tailings stream, in terms of treatment time, ability to treat higher solids streams, and ability to add flocculant in various physical states (solids, slurries, solutions, and the like).

EXAMPLES

Examples 1 to 4

A 0.5 wt% aqueous stock solution of polyethylene oxide (PEO) having a molecular weight of 8,000,000 Da available as UCAR FLOC™ 309 from The Dow Chemical Company are prepared by dissolution of the PEO in process water with magnetic mixing. Solutions are equilibrated without stirring for at least another 2 hours prior to use. Oil sands MFT tailings diluted to 30 wt% solids are shaken for 10 minutes in a horizontal shaker before dispensing about 5g by pipette into 10 mL glass vials.

Acoustic mixing of the flocculant solution and tailings is accomplished using a RESODYN™ LABRAM Mixer (Butte, MT). The tailings and any process water needed to maintain the desired solids loading are added by pipette to a 10 mL glass vial; and initially

combined using brief exposure to a vortex mixer. Polymer solution is added by pipette to the vial to provide 1,000 ppm PEO with respect to the tailings solids. The vial is capped and placed in the acoustic mixer for the desired mixing time and intensities. The intensities for Examples 1 to 4 are as follows: Example 1 is 50% intensity, Example 2 is 60%
 5 intensity, Example 3 is 70% intensity, and Example 4 is 80% intensity. After the acoustic mixing for various times, in seconds, the vials are immediately transferred to a liquid handling robot (Symyx Extended Core Module, Sunnyvale, CA) for imaging. An image of the sample is collected every minute for the first 15 minutes of settling; a final image is collected after 20 hours. The digital images are processed with an algorithm to determine
 10 the relative mud heights (normalized to the total sample height) as a function of settling time.

The settling results for Examples 1 to 4 are provided in Table 1.

Table 1

Example	1	2	3	4
Normalized Mud Height after 20 hours				
@ mixing for 10 sec	0.85	0.757	0.755	0.726
@ mixing for 20 sec	0.695	0.708	0.707	0.716
@ mixing for 30 sec	0.715	0.746	0.753	0.721
@ mixing for 60 sec	0.683	0.631	0.722	0.755

Good water release is observed over the range of intensities from 50 to 80%, in as little as 10 seconds mixing time, demonstrating the effectiveness of acoustic mixing in combining highly dissimilar viscosity liquids (tailings and flocculant solution). Higher
 20 mixing intensities (60-80%) improve the water release at short mixing times (10 seconds).

Examples 5 to 11

A 0.4 wt% aqueous stock solution of polyethylene oxide (PEO) having a molecular weight of 8,000,000 Da available as POLYOX™ WSR-308 from The Dow Chemical Company is prepared by dissolution of the PEO in process water with magnetic mixing.

5 Solutions are equilibrated without stirring for at least another 2 hours prior to use. Oil sands MFT tailings diluted to 30 wt% solids are weighed into 4 oz plastic jars, and mixed with a spatula to incorporate the dilution water. The aqueous polymer flocculant solution is added by pipet to provide 1,000 ppm PEO with respect to the dry tailings solids, and the jar is capped and placed in the sample chamber of the acoustic mixer. A total weight of
10 approximately 100 g is mixed at a time for 30 or 60 seconds at 60, 70 or 80% mixing intensity. Immediately after mixing, the contents of the jars are carefully and rapidly transferred to 100 mL glass graduated cylinders for settling. Images of the cylinders as a function of settling time are collected using a digital camera.

15 Compositions, mixing parameters, and water release after 20 hours for Examples 5 to 11 are shown in Table 2.

Table 2

Example	5	6	7	8	9	10	11*
PEO, ppm	1000	1000	1000	1000	1000	1000	0
Intensity, %	60	60	70	70	80	80	80
Mixing Time, sec	30	60	30	60	30	60	30
Final MFT Solids, %	30	30	30	30	30	30	30
MFT Sample Size, g	66.5	66.5	66.5	66.5	66.5	66.5	66.5
PEO Solution, mL	6.9	6.9	6.9	6.9	6.9	6.9	0
Process Water, mL	41.6	41.6	41.6	41.6	41.6	41.6	48.5
Solids, %	40.8	39.1	40.9	38.2	40.9	36.5	30.3
Water Release, %	38	33	38	30	38	25	1

*Not an Example of the invention

Examples 12 to 19

A 0.4 wt% aqueous stock solutions of polyethylene oxide (PEO) having a molecular weight of 8,000,000 Da available as POLYOX WSR-308 from The Dow Chemical

5 Company is prepared by dissolution of the PEO in process water with magnetic mixing. Solutions are equilibrated without stirring for at least another 2 hours prior to use. An oil sands MFT tailings, different from the one evaluated in Examples 1 to 12, diluted to 34.6 wt% solids are weighed into 4 oz plastic jars, and mixed with a spatula to incorporate the dilution water. The aqueous polymer flocculant solution is added by pipet to provide 1,000
10 ppm of PEO with respect to the tailings solids, and the jar is capped and placed in the sample chamber of the acoustic mixer. A total weight of approximately 100 g is mixed at a time for 30 or 60 seconds at 50, 60, 70 or 80% mixing intensity. Immediately after mixing, the contents of the jars are carefully and rapidly transferred to 100 mL glass graduated cylinders for settling. Images of the cylinders as a function of settling time are collected
15 using a digital camera.

Compositions, mixing parameters, and water release after 20 hours for Examples 12 to 19 are shown in Table 3.

Table 3

Example	12	13	14	15	16	17	18	19*
PEO, ppm	1000	1000	1000	1000	1000	1000	1000	0
Intensity, %	50	60	60	70	70	80	80	60
Mixing Time, sec	30	30	60	30	60	30	60	30
Final MFT Solids, %	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8
MFT Sample Size, g	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6
PEO Solution, mL	9.4	9.4	9.4	9.4	9.4	9.4	9.4	0
Process Water, mL	8.4	8.4	8.4	8.4	8.4	8.4	8.4	17.7
Solids, %	35.5	36.3	35.2	36.8	35.1	36.4	33.3	32
Water Release, %	15	18	14	20	14	18	7	1

20 *Not an Example of the invention

What is claimed is:

1. A process for flocculating and dewatering a mineral suspension, comprising the steps:
 - i) providing a mineral suspension to an acoustic mixer,
 - ii) providing a flocculant composition to said acoustic mixer,
 - and
 - iii) acoustically mixing the mineral suspension and the flocculant composition to provide a flocculated mineral suspension.
2. The process of Claim 1 wherein the flocculant is added to the mineral suspension before, during, or after addition to the acoustic mixer.
3. The process of Claim 1 further comprising the step
 - ii) a) providing a coagulant to said acoustic mixer.
4. The process of Claim 1 further comprising the step:
 - iv) adding the flocculated mineral suspension to at least one centrifuge to dewater the flocculated mineral suspension and form a high solids cake and a low solids centrate.
5. The process of Claim 1 further comprising the step:
 - v) adding the flocculated mineral suspension to a thickener to dewater the flocculated mineral suspension and produce a thickened mineral suspension and clarified water.
6. The process of Claim 1 further comprising the step:
 - vi) adding the flocculated mineral suspension to at least one deposition cell such as an accelerated dewatering cell for dewatering.
7. The process of Claim 1 further comprising the step:
 - vii) spreading the flocculated mineral suspension as a thin layer onto a sloped deposition site.
8. The process of Claim 1 wherein the mineral suspension is an aqueous suspension of oil sands tailings.
9. The process of Claim 1 wherein the flocculant composition comprises one or more of a polyacrylate, a polymethacrylate, a polyacrylamide, a partially-hydrolyzed polyacrylamide, a poly(ethylene oxide) homopolymer, a poly(ethylene oxide) copolymer, a

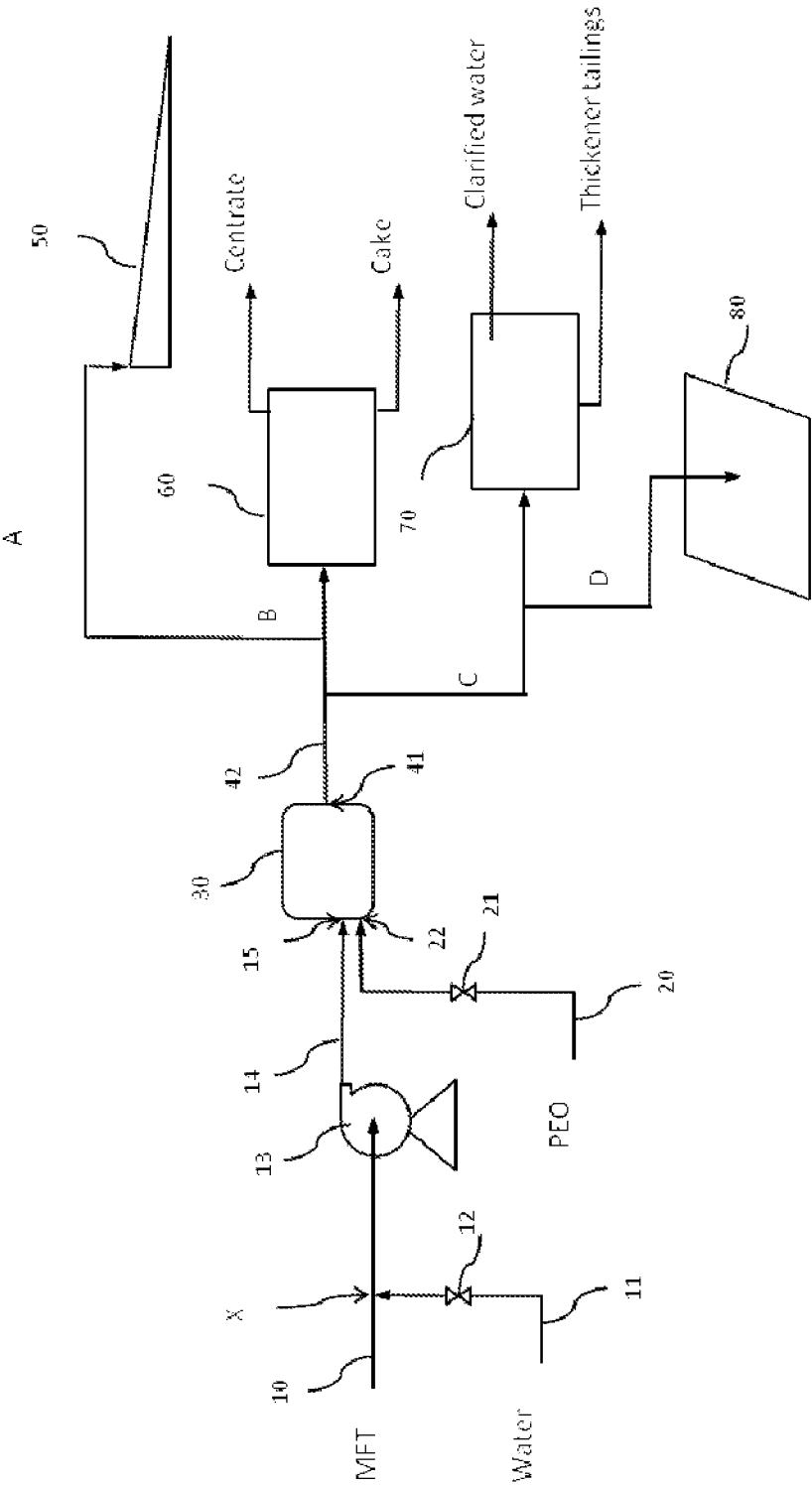
cationic derivatives of polyacrylamide, a polydiallyldimethylammonium chloride (pDADMAC), a copolymer of DADMAC, a cellulosic material, a chitosan, a sulfonated polystyrene, a linear and/or branched polyethyleneimine, a polyvinylamine, a polyalkylene glycol, a polyquat/hyalauronic acid, a polyacrylic, a polyacrylamide(acrylic acid) copolymer, a poly(acrylamide-co-diallyl dimethylammonium chloride), guar, a hydrophobically alkali-soluble emulsion, an alkali-swellaable emulsion, a hydrophobically modified ethoxylated urethane polymer, or mixtures thereof.

10. The process of Claim 1 wherein the flocculant composition comprises a poly(ethylene oxide) (co)polymer composition comprising a poly(ethylene oxide) homopolymer, a poly(ethylene oxide) copolymer, or mixtures thereof.

11. The process of Claim 10 wherein the poly(ethylene oxide) copolymer is a copolymer of ethylene oxide with one or more of epichlorohydrin, propylene oxide, butylene oxide, styrene oxide, an epoxy functionalized hydrophobic monomer, glycidyl ether functionalized hydrophobic monomer, a silane-functionalized glycidyl ether monomer, or a siloxane-functionalized glycidyl ether monomer.

12. The process of Claim 10 wherein the poly(ethylene oxide) (co)polymer has a molecular weight of equal to or greater than 1,000,000 Da.

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/042569

A. CLASSIFICATION OF SUBJECT MATTER

INV. C02F1/34 B01F11/00 C02F11/14 C10G1/04
ADD. C02F1/38 C02F1/56 C02F11/12 C02F103/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C02F B01F C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, COMPENDEX, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/082367 A1 (BERGER ALEXSANDRO [BR] ET AL) 24 March 2016 (2016-03-24)	1-3,8-12
Y	claim 1 claim 12 claim 14 paragraph [0120] - paragraph [0134] -----	4-7
X	US 2014/271321 A1 (MADERUD CARL-JOHAN [SE] ET AL) 18 September 2014 (2014-09-18) example 1 example 2 -----	1-9
X	RU 2 214 972 C1 (000 TS PRIKLADNOJ AKUSTIKI; AKVASERVIS AOOT) 27 October 2003 (2003-10-27)	1-3,8
Y	abstract ----- -/-	4-7



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 September 2017

Date of mailing of the international search report

15/09/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Janssens, Christophe

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/042569

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 34 09 107 A1 (NAGY ADALBERT DR ING) 26 September 1985 (1985-09-26) claim 1 claim 4	1,2
Y	----- WO 2016/019213 A1 (DOW GLOBAL TECHNOLOGIES LLC [US]) 4 February 2016 (2016-02-04) figure 1 -----	4-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/042569

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016082367	A1	24-03-2016	AR 096108 A1 09-12-2015
			EP 2988844 A2 02-03-2016
			US 2016082367 A1 24-03-2016
			WO 2014125130 A2 21-08-2014
US 2014271321	A1	18-09-2014	CN 103890204 A 25-06-2014
			EP 2768995 A2 27-08-2014
			ES 2613643 T3 25-05-2017
			JP 6139538 B2 31-05-2017
			JP 2015501377 A 15-01-2015
			KR 20140091557 A 21-07-2014
			US 2014271321 A1 18-09-2014
			WO 2013057136 A2 25-04-2013
RU 2214972	C1	27-10-2003	NONE
DE 3409107	A1	26-09-1985	NONE
WO 2016019213	A1	04-02-2016	CA 2956460 A1 04-02-2016
			CN 106573210 A 19-04-2017
			US 2017216791 A1 03-08-2017
			WO 2016019213 A1 04-02-2016