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(71) Applicant: **Andritz, Inc.**
Glens Falls, NY 12801-3636 (US)

(72) Inventor: **Tuuri, Sami**
Helsinki 11610 (FI)

(74) Representative: **HOFFMANN EITLE**
Patent- und Rechtsanwälte
Arabellastraße 4
81925 München (DE)

(54) **Method for measuring and controlling digester or impregnation vessel chip level by means of measuring chip pressure**

(57) A method and system for determining chip pressure in a vessel (10) containing a slurry of lignocellulosic material including: sensing a total static pressure of the slurry in the vessel (10); sensing a hydrostatic pressure of the liquor in the vessel (10), and determining the chip pressure based on a difference of the sensed total static pressure of the slurry and the sensed hydrostatic pressure of the liquor.

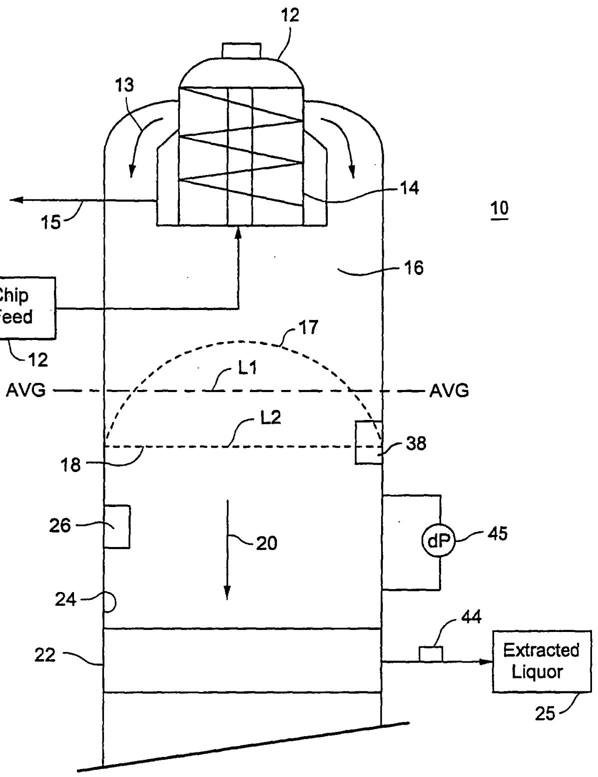

Fig. 1

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Description

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/024,654 filed January 30, 2008, the entirety of which is incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to chemical treatment of lignocellulosic fibrous material in pulp production and, particularly, to automatic sensing and control systems in a chemical digester or impregnation vessel processing the fibrous material.

[0003] Lignocellulosic material, such as wood chips, are typically introduced to the top of a digester or impregnation vessel. Heat, pressure and liquor are also introduced to the vessel to process the material. The processing of wood chips may be continuous as chips are introduced to the top of the vessel while processed chips are discharged from the bottom of the vessel. The level of wood chips in the vessel is monitored to ensure that an appropriate amount of chips are in the vessel and that the chips are retained in the vessel for an appropriate period of time. Accurate information regarding the chip level is needed to properly regulate the flow of chips to the top of the vessel, the discharge of chips from the bottom of the vessel, and the pressure of the chips in the vessel.

[0004] The chip level is conventionally measured by strain gauge sensors on paddles extending into the digester or impregnation vessel. Typically three or four paddles are arranged in a digester vessel. Each paddle includes strain gauge sensors that measure the forces applied by the moving chip column in the vessel to the paddles. The strain gauge sensors generate voltage signals indicative of the forces applied by the chip column to the paddle. The signals generated by the strain gauges are used to calculate a chip level in the vessel and for controlling the chip processing in the vessel.

[0005] The strain gauges require paddles that extend into the chip flow and, thus, partially obstruct the flow. The strain gauges provide valid data when there is a chip flow and tend not to provide valid data when the chips are stationary in the vessel. Similarly, the data generated by the strain gauges is highly sensitive to the chip flow rate through the vessel which may not be a constant rate.

BRIEF DESCRIPTION OF THE INVENTION

[0006] In view of these concerns regarding strain gauges, there is a need for an alternative or supplementary sensor and method to detect chip levels and other conditions in the vessel. In addition, there is a need for methods and systems to assist in controlling the chip pressure in a vessel.

A novel system and method has been developed to determine the chip level in a vessel, e.g., a digester and impregnation vessel, based on chip pressure in the vessel. The novel system includes determining the chip pressure based on a differential of the total slurry pressure in the vessel and the hydrostatic pressure due to the liquor component of the slurry.

[0007] A pressure sensing element has been developed for a vessel containing a slurry of lignocellulosic chip material, the element including: a first pressure sensing surface in contact with the slurry, wherein the first pressure sensing surface generates a signal representative of total static pressure of the slurry; a second pressure sensing surface generating a signal representative of a hydrostatic pressure of liquor in the slurry, and a pressure difference transmitter receiving the signals generated by the first and second pressure sensing surfaces and outputting a signal indicative of the chip pressure. A filter, such as a screen, perforated plate, mesh or other device in front of the second pressure sensing surface may block chips and pass liquor to the second pressure sensing surface.

[0008] A method has been developed for determining a pressure of the chips in a vessel containing a slurry of lignocellulosic material, the method comprising: sensing a total pressure of the slurry in the vessel; sensing a hydrostatic pressure of the liquor in the vessel, and determining the pressure of the chips based on a difference of the sensed total pressure of the slurry and the sensed hydrostatic pressure of the liquor.

[0009] A method has been developed to calibrate an algorithm to determine chip level comprising: measuring the liquor level in a vessel; measuring a chip pressure in the vessel; determining a calculated chip level using an algorithm to calculate the chip level based on the chip pressure; while varying the liquor level in the vessel, detecting a transition between a steady state chip pressure and a varying chip pressure; determining a difference existing at the transition between the liquor level and the calculated chip level; and adjusting the algorithm to compensate for the difference.

[0010] A method has been developed for processing lignocellulosic chip material in a continuous flow vessel, the method comprising: determining a chip pressure of the chip material based on a difference of a sensed total pressure of the slurry and a sensed pressure of the liquor; comparing the determined chip pressure of the chip material to a predetermined desired chip pressure; and adjusting a flow rate of the chip material through the vessel based on the comparison of the determined chip pressure to the predetermined desired chip pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIGURE 1 is a schematic diagram of a treatment vessel for lignocellulosic fibrous material.

[0012] FIGURE 2 is a schematic diagram of a front view of a pressure sensing element.

[0013] FIGURE 3 is a schematic diagram of a cross-sectional view of the pressure sensing element.

[0014] FIGURE 4 is a is a chart showing levels of chips and liquor in a vessel and chip pressure during a calibration process for an algorithm determining chip level.

DETAILED DESCRIPTION OF THE INVENTION

[0015] FIGURE 1 is a schematic diagram of a treatment vessel 10 for lignocellulosic fibrous material (referred to herein as "wood chips" or simply "chips"). The vessel 10 may be, for example, a digesting vessel in a pulping system, or may be one of two or more vessels, where one vessel is a digesting vessel and the other vessel is an impregnation vessel. Chemical digesters and impregnation vessels are typically used to convert wood chips into a cellulose pulp from which paper products may be made. These vessels apply pressure, heat and cooking liquor to the chips. The digester and impregnation vessels are generally vertical columns often having heights greater than about 30 meters (100 feet). The vessels may be used in continuous flow processes, in which a slurry of wood chips and liquor is continually introduced and discharged to and from the vessel. Alternatively, the vessel may be used in batch processes wherein a slurry is sequentially introduced to the vessel, processed and discharged.

[0016] A conventional chip feed system 12 provides a generally continuous flow of woods chips to a top separator 14 at the top of the vessel 10. The feed system mixes the chips with white liquor to form a slurry that flows to the top separator 14. The chips are discharged 13 from the top (or bottom) of the separator and a portion of the liquor is extracted 15 from the separator and vessel.

[0017] The vessel may be a vapor-phase digester or a hydraulic digester. A hydraulic vessel is typically filled completely with cooking liquor to the top of the vessel 14. A vapor phase vessel typically has an upper gas filled region 16 above the upper level chips and liquor in the vessel. In hydraulic and vapor-phase digester vessels, the chips form an upper surface 17 that is generally referred to as the chip level of the vessel. The chip level may be at, above or below the liquor level 18 in a vapor phase vessel. In a hydraulic vessel, the chip level is typically below the liquor level, which fills the vessel during normal chip processing operations. The chip level 17 may be generally horizontal and may have an upper concave surface. An average elevation of the chip level is designated as L_1. Below the chip level 17 and the liquor level 18 (which is designated as L_2), the chips compact under the hydrostatic pressure of the liquor and the weight of the chip column in the vessel. In a continuous flow vessel, the chips migrate downward from the chip level 17 towards the bottom of the vessel.

[0018] As the wood chips sink down through the chip column in the vessel (see arrow 20), liquor, heat and pressure act on the chips to dissolve and otherwise separate the fibers in the chips from the network of fibers that form the untreated wood chips. At one or more elevations in the vessel, liquor extraction screens 22 may be arranged on the sidewall 24 of the vessel. A portion 25 of the liquor in the vessel is extracted through the screens 22 and, at least temporarily, removed from the vessel. The treated wood chips are discharged from the bottom of the vessel 10 for further treatment.

[0019] To monitor chip pressure, a pressure sensing element 26 is placed inside the vessel or on the vessel sidewall 24. Preferably, the pressure sensing element is positioned above the uppermost extraction screens 22 and below the lowermost level of the chips during normal continuous flow operation of the vessel. The pressure sensing element 26 provides data regarding the pressures in the vessel and particularly the total pressure of the slurry in the vessel, the hydrostatic pressure of the liquor in the slurry, and indirectly the pressure attributable to the chips in the slurry. The measured chip pressure is used to determine a calculated chip level 17 in the vessel, where the calculated chip level L_1 is an average level of the upper chip surface 17.

[0020] In general, the total static pressure in the vessel, at any given elevation of the vessel, is the sum of the hydrostatic pressure the liquor and the weight of the chip column above that elevation (referred to herein as the "static chip pressure" or just "chip pressure"). The chip pressure indicates the amount of chip compaction in the vessel at the elevation in the vessel at which the pressure is determined. The total static pressure of the slurry may be determined as the static pressure applied by the slurry to a unit area at a given depth in the vessel. In a hydraulic or vapor phase vessel, the total static pressure should vary in direct proportion to the depth of the slurry. Similarly, the static chip pressure should vary in direct proportion to the distance between the chip level and the elevation at which the static pressure is measured. In view of the relationship between static pressure and depth, the upper level of the chips in a vessel can be determined from a pressure measurement and the elevation in the vessel at which the pressure is measured. In addition, the chip level determination may be influenced by the liquor level in the vessel and, thus, measuring the liquor level may be useful in determining chip level.

[0021] The total static pressure of the slurry is the combination of the hydrostatic pressure of the liquor and the static chip pressure. Generally, the hydrostatic pressure of the liquor is much larger than the static chip pressure and, thus, the hydrostatic pressure of the liquor is only slightly smaller than the total static pressure of the slurry. In view of the difficulty in directly measuring the low static chip pressure, the pressure element 26 directly measures the large values of the hydrostatic pressure of the liquor and the static pressure of the slurry. The difference between the total static pressure of the slurry and the hydrostatic pressure of the liquor is used to determine the static chip pressure.

[0022] FIGURES 2 and 3 are schematic diagrams of a front view and cross-sectional view of the pressure sensing element 26. The pressure sensing element 26 includes a first pressure sensor surface 28 in direct contact with the slurry of wood chips and liquor, and a second pressure sensor surface 30 in direct contact with only the liquor and not the chips. The pressure sensor surfaces 28, 30 may be each a diaphragm. A filter 32, such as a screen used in the extraction screen, perforated plate, mesh or porous disc, may shield the second pressure sensor surface 30 from the chip flow and allow liquor to flow through to the surface 30. The first and second pressure sensing surfaces may be attached to an inside surface of the sidewall 24 of the vessel or to a portal in the sidewall of the vessel. The pressure sensing element 26 may include a substrate or housing mounted in or to the vessel wall and that supports the first and second pressure sensor surfaces 28, 30. Alternatively, the pressure sensor surfaces 28, 30 may be each be mounted in an aperture 34 in the sidewall 24 of the vessel. A cylinder 36 mounted in the vessel wall or the substrate of the pressure sensing element may support the filter 32 and provide a chamber for the fluid pressing against the second pressure sensor surface 30.

[0023] The first and second pressure sensor surfaces 28, 30, are preferably near each other and part of the same pressure sensing element 26. The pressure sensing element may be one of many types of sensors commonly used to measure liquid level in the tank or vessel. Depending on its function, the pressure sensing element may not require a filter to block the flow of chips. The chip filter 32 may be a screen, perforated plate, mesh, honeycombed plate or other device that blocks the flow of chips and allows passage of the liquor to the pressure sensor surface 30. The openings, e.g., apertures, slots or passages, in the filter are sufficiently narrow to block chips. Liquor passes through the filter and applies pressure to the second pressure sensor surface 30.

[0024] The two pressure sensing surfaces 28, 30 are preferably at the same elevation, e.g., height, in the vessel to ensure equal liquor hydrostatic pressure on both sensing surfaces. By way of example, the pressure sensing surfaces may be at an elevation in the vessel five to ten meters below the normal chip level. The sensing element surfaces are also preferably installed above the uppermost extraction screens 22 in the vessel. The exact installation location in a vessel, distance between the sensors and the manner of installation of the sensing surfaces 28, 30 and their associated pressure element 26 is a matter of design choice and may be defined by the design and construction of the digester or impregnation vessel and type of the digester. For example, if one of the pressure sensing surfaces is installed in an aperture in the sidewall of the vessel, the horizontal distance between the surface 30 in the aperture and the surface 28 on the sidewall may be greater than if the two surfaces 28, 30 are mounted on the sidewall.

[0025] The sensing elements 26 may be installed on the inside wall 24 of the vessel or on the digester wall, or alternatively inside the vessel such as on an outside wall of a center pipe in the vessel or on a post extending from the outside wall 24 to inside the vessel. Further, the pressure sensing elements 26 should be installed so that the velocity and momentum of the chips have a minimal affect to the measured pressure signal. The sensor surfaces 28, 30 should preferably be arranged at an angle between parallel to the direction of the chip flow, e.g., the chip velocity vector (see slurry flow direction arrow 20) or 10 degrees inclined to the chip velocity vector (see arrow 20). Applying a slight angular tilt, e.g., up to 20 degrees and preferably about 5 degrees, to the sensor surface 28 so that the lower edge of the surface extends further into the slurry than does the upper surface edge may make the sensor surface 28 more sensitive to static chip pressure. However, adding excessive angular tilt to the sensor surface 28 may cause the velocity of the chips impacting on the sensor surface to skew the response of the sensor surface 28.

[0026] The surface area of each of the pressure sensing surfaces 28, 30, and particularly the surface 28 that is in contact with wood chips, should preferably be relatively large, such as within twenty percent of 0.1 meters squared (m^2). The large surface area of the surface of the pressure sensing surface 28 provides sufficient contact area to sense the chips that tend to contact the surface at various angles, have different chip shapes and sizes, and may be more or less dense in the slurry in the vessel. The surface areas of the pressure sensing surfaces 28 and 30 may be different. For example, the surface of sensing surface 30 that is not in contact with chips may have a smaller area than the surface of sensing element 28 that is in contact with the chips. If the surface areas of the pressure sensing surfaces 28, 30 are different, the electronics of the pressure sensor are set up to account for the surface areas of the sensing elements and to determine the pressure given the area of the surfaces.

[0027] The relatively large surface area, e.g., 0.1 m^2, of the sensing surfaces 28, 30 minimizes the effect of variations in these parameters. Accordingly, large surface area sensing surfaces minimize undesirable influences on the signals generated by the surfaces that could degrade the accuracy of the pressure measurements. The parameters of contact angle, chip shape, and the density of chips may vary with time during the process in the vessel.

[0028] The first pressure sensor surface 28, which is in direct contact with the wood chips, measures the total static pressure of the slurry of the wood chips and liquor. In contrast, the second pressure sensor surface 30 measures the hydrostatic pressure of the liquor. The second pressure sensor surface 30 does not measure the pressure of the chips, because the sensor surface 30 is behind a chip filter 32 and is shielded from the chips. The static pressure due to the chips is determined from the difference between the measurements of the hydrostatic liquor pressure sensed by pressure sensor surface 30 and the total static pressure made by pressure sensor surface 28.

[0029] Due to the small magnitude of the static chip pressure related to the hydrostatic pressure of the liquor, it is preferable to use a pressure difference transmitter, such as a differential pressure (DP) sensor 35. The pressure sensing element 26 may includes a DP sensor 35 having as inputs capillary pressure tubes 36, 38 that are hydraulically coupled to the pressure sensing surfaces 28, 30. The DP sensor measures the static pressure in both tubes 36, 38 and outputs a signal representative of the difference between the pressures in the capillary tubes. The tubes are each connected to a small fluid cavity 40 behind a respective one of the pressure sensing surfaces. The fluid filled cavities 40 serve as pressure repeaters to communicate the pressure applied to the surfaces 28, 30 to the capillary tubes. As the slurry presses against the first pressure sensor surface 28, the surface deflects and applies a pressure in the cavity 40 and the capillary tube 36 that corresponds to the total static pressure of the slurry. Similarly, as the liquor presses against the diaphragm of the second pressure sensing surface 30, the pressure in the cavity 40 and the capillary tube 38 is representative of the hydrostatic pressure of the liquor on the opposite side of the diaphragm.

[0030] The liquor may be highly alkaline and at a high temperature. The pressure sensing surfaces 28, 30 serve as pressure repeaters transferring the pressure of the slurry and the liquor to the hydraulic liquid in the capillary tubes. The diaphragm surfaces 28, 30 allow the pressure of the slurry and liquor to be applied to the DP sensor 35 without exposing the sensor to the alkaline and temperatures of the liquor.

[0031] It is preferable to include a liquor density sensor 44 (Fig. 1) to measure the liquor density (R2). Alternatively, the liquor density may be measured by using a pressure difference based sensor 45. Knowing the liquor density allows for compensations to be made in the determination of chip pressure if the liquor density changes during the processing of the chips in the vessel. Further, a liquor level sensor 38 may be used to determine the liquor level 18 in the vessel. The liquor level may be used in the calculation to determine the chip level from chip pressure.

[0032] Chip pressure affects chip compaction in the vessel. The chip pressure at each elevation in the vessel is an indicator of the compaction of the chips in the vessel at that elevation and lower elevations in the vessel. A profile of chip compaction over the entire digester length can be prepared based on the chip pressure as measured at various elevations in the vessel. The compaction profile can be used, for example, to determine the chip retention period in the vessel and at various zones in the vessel. For example, the compaction profile may be used to determine the retention time of chips in a cooking zone of a digester vessel.

[0033] Chip pressure can be used to control the vessel, e.g., the flow of chips into and out of the vessel, to better stabilize the chip compaction profile in the vessel and thereby minimize variations in the quality of the processed chips discharged from the vessel. The chip pressure measurement provides data helpful to stabilize the impregnation or cooking processes in the vessel. The chip pressure data may be used by a controller for the vessel to adjust the control parameters for the vessel, e.g., flow rates of chip input and discharge to the vessel, to maintain a constant chip pressure at selected elevations in the vessel.

[0034] Knowing and controlling the chip level in a vessel is generally needed to reliably control the chip pressure in the vessel. For example, a computer controller 42 may monitor the chip pressure signal output from the pressure sensing element and compare the measured chip pressure to a desired chip pressure. If the difference between the measured chip pressure and the desired chip pressure exceeds a predetermined range, e.g., within ten percent of the desired chip pressure, the controller may adjust the slurry flow rate into the top separate or the chip discharge rate from the bottom of the vessel to reduce the difference.

[0035] The pressure sensing elements 26 may be used to monitor chip level in the vessel and control the chip pressure in the vessel. Using the data from the pressure sensing elements, an operator or an automatic control system 46 may, for example, select to control the chip level in the vessel or to control the chip pressure in the vessel. The control system may regulate the slurry flow into the vessel or discharge rate of processed chips from the vessel. If the controller 42 is in a mode to maintain the chip level within a predetermine range of elevations in the vessel, the controller may calculate the chip level based on the chip pressure and, if the calculated chip level is outside of an acceptable range of elevations, increase or reduce the slurry flow into the top separator or the chip discharge rate from the bottom of the vessel to raise or lower the chip level to the acceptable range. Further, the controller 42 may compare the measured chip pressure to a range of acceptable limits for the chip pressure in the vessel and adjust the flow of chips into or out of the vessel to keep the chip pressure within these limits. Alternatively, the control system may maintain a constant chip pressure in the vessel provided that the chip level does not exceed a predetermined range of elevations in the vessel. By keeping a constant chip pressure, chip density variations can be minimized in the chip compaction profile for the vessel. Further, controlling the chip pressure in a vessel (rather than directly controlling the chip level) may be helpful in reducing the kappa number variation by compensating for the effects of chip density and air content variations and disturbances.

[0036] The chip pressure is a function of the height of the chip column above the sensing element 26, the height of the liquor column in the vessel above the sensing element, liquor density and chip density in the vessel. An algorithm for determining chip pressure (PC) for a range of chip levels (L1) and liquor levels (L2) above the sensor element 22 is as follows:

[0037]

$$PC = (R1-R2)*G*min\{L1; L2\}+R1*G*max\{L1-L2; 0\}$$

[0038] Where: PC is chip pressure (Pa - atmospheric pressure); L1 is the average chip level in the vessel [meters (m)]; L2 is the liquor level in the vessel [m]; R1 is the density of chips entrained by liquor in the vessel [kg/m^3]; R2 is the density of free liquor [kg/m^3], and G is the gravitational force constant [kg/(ms^2)]. The term min{L1; L2} indicates a selection of the smaller value of L1 and L2. Similarly, max {L1-L2; 0} indicates a selection of a positive value of the difference between L1 and L2 or a selection of zero if the difference is a negative value.

[0039] To determine the chip level L1 from the above formula, the following algorithms may be applied:

[0040] Solution 1: If L1<L2 then

$$L1 = k1 * PC/[(R1-R2) * G]$$

, where k1 is a calibration constant.

[0041] Solution 2: If L1>L2 then

$$L1 = [k1*PC + k2 *(R2*G*L2)]/(R1*G)$$

, where k1 and k2 are calibration constants.

[0042] The Solution 1 formula is selected if the liquor level is above the chip level and the Solution 2 formula is selected if the chip level is above the liquor level. A determination may be made using both the Solution 1 and 2 formulas, and the checking if the pre-condition for L1 and L2 relationship is valid. The result obtained by the valid formula (Solution 1 or 2) is then selected as the correct chip level estimate L1.

[0043] A measured liquor density R2 from sensor 44 or 45 may be used to estimate of the density of liquor impregnated wood chips (R1) using the following formula:

[0044]

$$R1 = Eps * RW + (1-Eps) * R2$$

[0045] EPS and RW are wood type specific parameters; Eps is the volume fraction of solid wood material in a porous wood chip; (1-Eps) is the volume fraction of liquor in a porous wood chip, and RW is solid wood density. For example, Eps may be in a range of 0.6 to 0.75, and RW may be in a range of 1300 kg/m^3 to 1650 kg/m3. It is assumed that wood chips are fully penetrated by liquor and no air remains inside wood chip.

[0046] FIGURE 4 is a chart 50 illustrating a chip level calibration technique. The horizontal axis represents time (nos. 1 to 39) in the operation of the vessel. The vertical axis 52 on the left hand side of the chart represents the height of the vessel, where the vessel is approximately 12 meters high. The vertical axis 54 on the right hand side of the chart represents static pressure of the chips within the vessel in kilo (1,000) of Pascal (Newtons per square meter).

[0047] The chip level calculated based on the data from the pressure sensing element 26 may be calibrated using the liquor level data collected by liquor level sensor 38 (see Fig. 1). The liquor level data is directly measured by the liquor level sensor and is treated as being accurate and suitable for use as a reference value for purposes of calibrating the chip level determination.

[0048] The calibration process varies the amount of liquor in the vessel such that the liquor level (line 58 in chart 4) rises above and then falls below the actual chip level. The actual chip level is preferably held constant during the calibration process. During this process, the chip level is determined (line 56) based on the chip pressure (line 60) using the algorithms described above.

[0049] The algorithm of Solution 2 indicates that chip level (L1) is a function of liquor level (L2) when the liquor level is below the chip level. The algorithm of Solution 1 indicates that the chip pressure does not vary with liquor level while the liquor level is above the chip level. When the liquor level rises or sinks through the chip level, the chip pressure should transition from a constant value to a changing value or vice versa. Assuming a constant chip level, the chip pressure 60 should begin to change when a falling liquor level 58 passes through the chip level. When the liquor level is below the chip level, the chip pressure should continue to change while the liquor level rises up to the chip level and thereafter the chip pressure should remain constant as the liquor level rises above the chip level.

[0050] During the calibration process, the pressure sensing element senses for changes 62, 68 in static chip pressure 60 while the liquor level is raised and lowered above and below a constant chip level. While the liquor level is above the chip level, the chip pressure 60 should remain constant (see time period 1 to t1 in Figure 4). At t1, the chip pressure begins to change 62 by transitioning from a constant pressure to a rising pressure. At that moment (t1), the liquor level is equal to the actual chip level. Because at t1 the determined chip level 56 should equal the measured chip level 56, the associated chip pressure change 62 is used to identify a calibration event for the determination of chip level. Any difference 64 at t1 between the determined chip level 56 and the measured liquor level 58 indicates an error in the algorithms used to determine chip level 56. For purposes of calibration, the measured liquor level 58 at t1 is treated as representing the actual chip level and the difference 64 is deemed an error in the chip level algorithms. In the example shown in Figure 4, there is about a one half of a meter (0.5 m) difference 64 between the determined chip level and the measured liquor level.

[0051] During the period from t1 to t2, the liquor level 58 is lowered further to about, for example, one meter below the chip level. In addition, the algorithms (Solution 1 and 2) for determining chip level are adjusted, such as by adjusting either or both of the calibration constants k1 and k2 in Solutions 1 and 2. In this example, the adjustment to the Solutions 1 and 2 causes the determined chip level to increase 66 by 0.5 meters at time t2. The actual chip level is not changed and only the determined chip level changes at transition point 66. During the period from t2 to t3, the actual and determined chip level remain constant and the liquor level transitions from a constant low level to a rising level. As the liquor level rises 58, the static chip pressure 60 drops because the liquor level is below the chip level. The dropping chip pressure is modeled by the algorithm of Solution 2. The cessation in the dropping chip pressure at t3, is taken as an indication that the liquor level is equal to the chip level and as a calibration event. At this second calibration event (t3), there is no error between the determined chip level 70 and the measured liquor level. The lack of an error indicates that the determined chip level is providing an accurate indication of the actual chip level and the calibration process is completed. If at the second calibration event (t3) a significant difference, e.g., greater than 0.1 meter, remained between the determined chip level and the liquor level, a further adjustment may be made to the algorithms of solutions 1 and 2 and the lowering and raising of the liquor level through the chip level described above may be repeated until the difference at a calibration event is reduced below an acceptable tolerance error level.

[0052] Potential benefits and improvements to determining pressure of the chips, using the chip pressure to estimate chip levels include: a continuous and reliable chip level measurement signal without need of a strain gauge or the calculations associated with strain gauges; a single pressure sensing element that provides data over a large operational range of the vessel; a reliable chip level signal even when the flow through the vessel is stagnant, such as during vessel shut-down; a chip level signal that is not influenced by chip velocity or the treated chip production rate of the vessel; a uniform and common pressure sensing element configuration for a variety of types of vessels (in other words, the pressure sensing element may be used in a variety of types of vessels); an accurate chip pressure signal for stabilizing the digester operation; an accurate chip pressure measurement to determine chip compaction profiles; on-line calibration by slowly ramping either chip or liquor level to a set point to detect chip pressure signal when levels are identical; lower component and instrumentation costs, and lower commissioning and start-up costs.

[0053] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

Claims

1. A pressure sensing element (26) for a vessel (10) containing a slurry of lignocellulosic chip material, the element comprising:

   a first pressure sensing surface (28) in contact with the slurry, wherein the first pressure sensing surface (28) generates a signal representative of a pressure of the slurry, which is sum of a hydrostatic pressure of liquor and chip pressure;
   a second pressure sensing surface (30) generating a signal representative of the hydrostatic pressure of the liquor, and
   a pressure difference transmitter (35) receiving the signals generated by the first (28) and second pressure

sensing surfaces (30) and outputting a signal indicative of the chip pressure.

2. The pressure sensing element (26) in claim 1 wherein the output signal from the pressure difference transmitter (35) is representative of a difference between the signals generated by the first (28) and second pressure sensing surfaces (30).

3. The pressure sensing element (26) in claim 1 or 2 further comprising a filter (32) between the slurry and the second pressure sensing surface (30), wherein the filter (32) passes liquor to the second pressure sensing surface (30) and blocks chip material from reaching the second pressure sensing surface (30).

4. The pressure sensing element (26) in any one of the preceding claims wherein at least the first pressure sensing surface (28) has an orientation in a range between parallel to a flow direction of the slurry and inclined at twenty degrees to the flow direction.

5. The pressure sensing element (26) in any one of the preceding claims wherein the pressure sensing element (26) is positioned in the vessel (10) above an uppermost extraction screen (22) in the vessel (10) and below an inlet separator (14) for the vessel (10).

6. The pressure sensing element (26) in any one of the preceding claims wherein the pressure sensing element (26) is mounted on an inside surface of an outer wall (24) of the vessel (10).

7. The pressure sensing element (26) in any one of the preceding claims wherein at least the first pressure sensing surface (28) has a surface area of approximately 0.1 meters squared.

8. A method for determining a pressure attributable to lignocellulosic chip material in a vessel (10) containing a slurry of the lignocellulosic material and liquor, the method comprising:

sensing a pressure of the slurry in the vessel (10);
sensing a pressure of the liquor in the vessel (10), and
determining the pressure attributable to the chips based on a difference of the sensed pressure of the slurry and the sensed pressure of the liquor.

9. The method of claim 8 wherein the pressure of the slurry is a static pressure sensed with a first pressure sensing surface (28) in contact with the slurry and generating a signal representative of the static pressure of the slurry.

10. The method of claim 8 or 9 wherein the pressure of the liquor in the slurry is sensed by a second pressure sensing surface (30) generating a signal representative of a hydrostatic pressure of the liquor in the slurry.

11. The method of any one of claims 8 to 10 wherein a filter (32) is positioned between the slurry and the second pressure sensing surface (30) and wherein chips are blocked by the filter (32) and the filter (32) passes liquor which contacts the second pressure sensing surface (30).

12. The method of claim 8 including determining a chip level (17) in the vessel (10) based on the determined pressure of the chips.

13. The method of claim 8 wherein the sensing of the pressures of the slurry and liquor occurs above an uppermost extraction screen (22) for the vessel (10).

14. The method of claim 8 wherein a chip level (L1) in the vessel (10) is determined by applying at least one of the following algorithms:

$$L1 = k1 * PC/[(R1 - R2) * G]$$

if L1 is greater than L2, and

$$L1 = [k1 * PC + k2 * (R2 * G * L2)]/(R1 * G)$$

if L2 is greater than L1,
where the PC is the determined pressure of the chips; the k1 and the k2 are calibration constants, the L1 is an average chip level in the vessel (10); the L2 is a liquor level in the vessel (10); the R1 is a density of the entrained chips in the slurry; the R2 is a density of liquor in the slurry, and the G is a gravitational force constant.

15. A method for calibrating an algorithm to determine chip level comprising:

measuring the liquor level in a vessel (10);
measuring a chip pressure in the vessel (10);
determining a calculated chip level using an algorithm to calculate the chip level based on the chip pressure;
while varying the liquor level in the vessel (10), detecting a transition between a steady state chip pressure and a varying chip pressure;
determining a difference existing at the transition between the liquor level and the calculated chip level, and adjusting the algorithm to compensate for the difference.

16. The method of claim 15 wherein the chip level in the vessel (10) is maintained substantially constant during the calibration method.

17. The method of claim 15 wherein the liquor level is raised and lowered above and below the chip level during the calibration method.

18. The method of claim 15 wherein the chip pressure is measured at an elevation in the vessel (10) below the chip level and the liquor level, and above a first extraction screen (22) in the vessel (10).

19. A method for processing lignocellulosic chip material in a continuous flow vessel (10), the method comprising:

determining a chip pressure of the chip material based on a difference of a sensed total pressure of the slurry and a sensed pressure of the liquor;
comparing the determined chip pressure of the chip material to a predetermined desired chip pressure, and adjusting a flow rate of the chip material through the vessel (10) based on the comparison of the determined chip pressure to the predetermined desired chip pressure.

20. The method of claim 19 wherein the predetermined desired chip pressure is a constant chip pressure. :

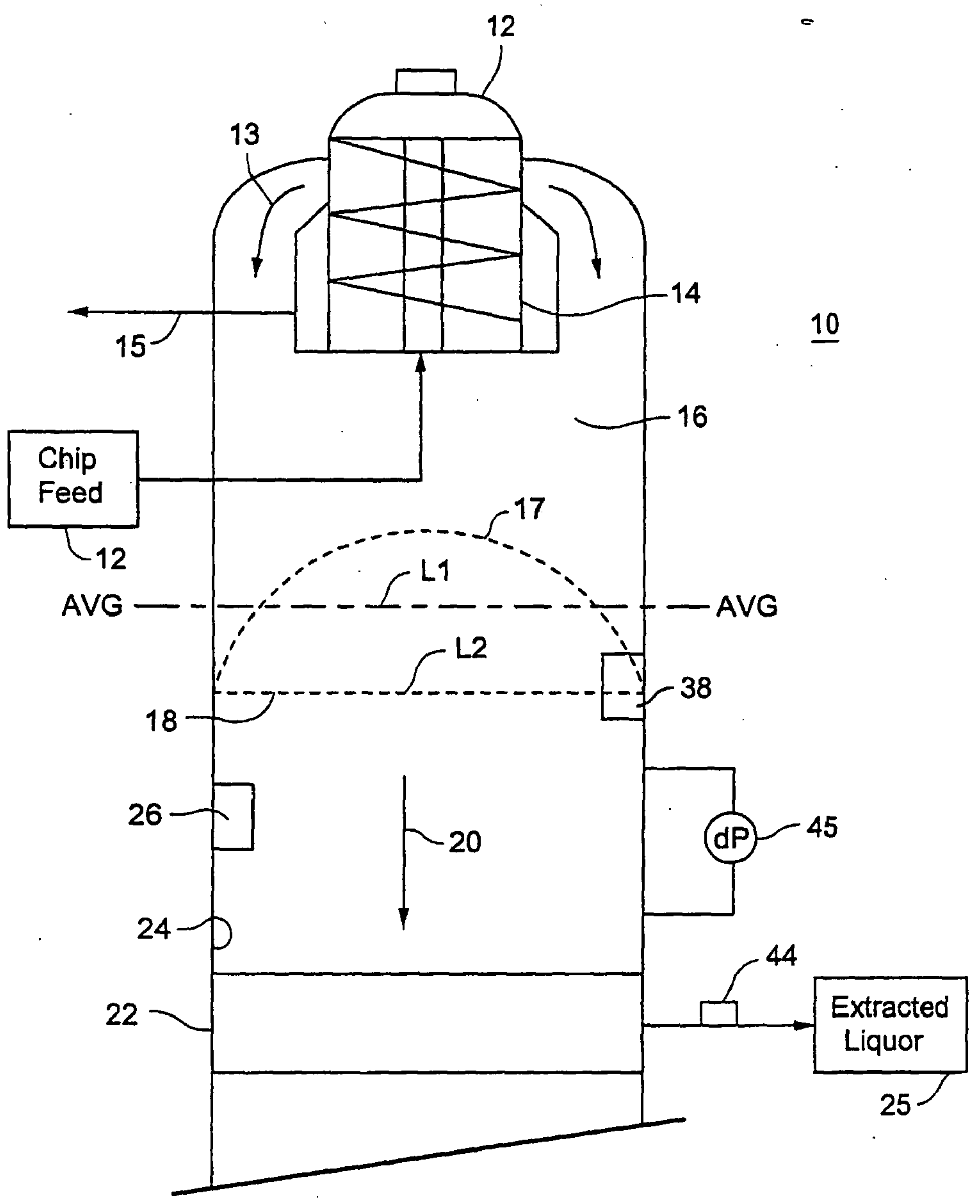
12
13
14
10
15
16
Chip Feed
12
17
L1
AVG
AVG
L2
18
38
26
20
dP
45
24
44
22
Extracted Liquor
25

Fig. 1

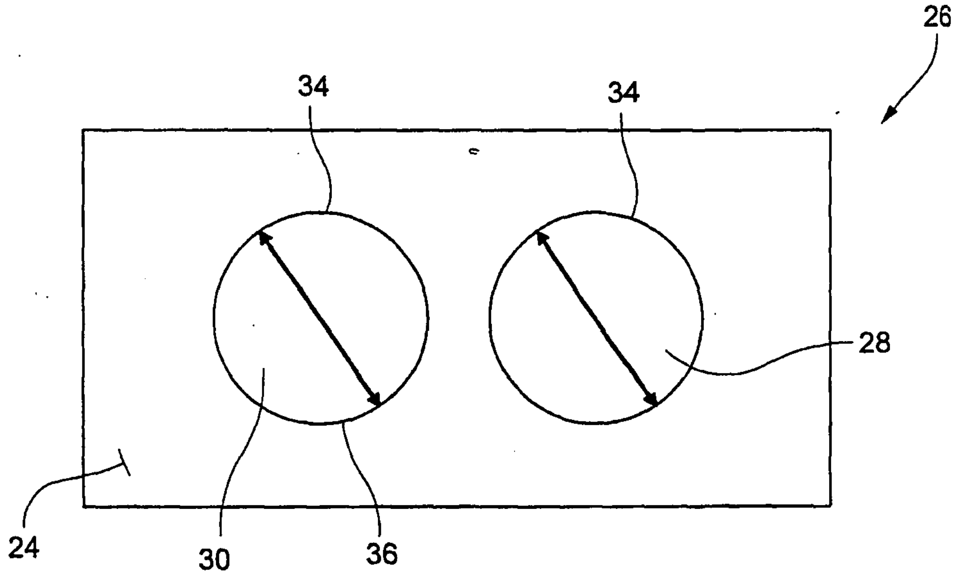
26
34
34
28
24
30
36

Fig. 2

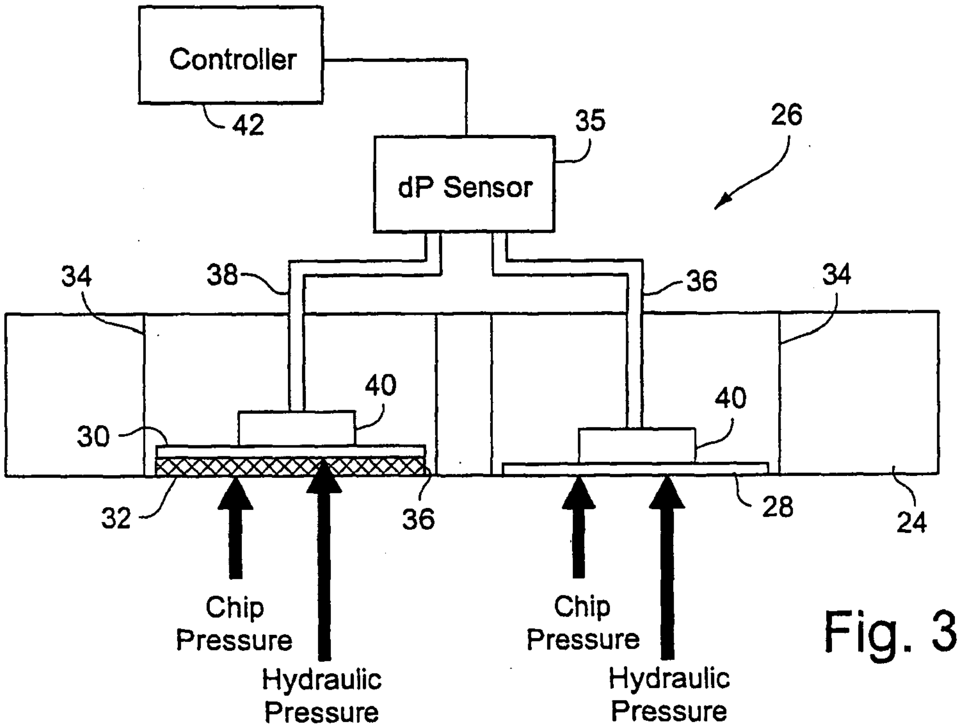
Controller
42
35
dP Sensor
26
34
38
36
34
40
40
30
32
36
28
24
Chip
Pressure
Hydraulic
Pressure
Chip
Pressure
Hydraulic
Pressure

Fig. 3

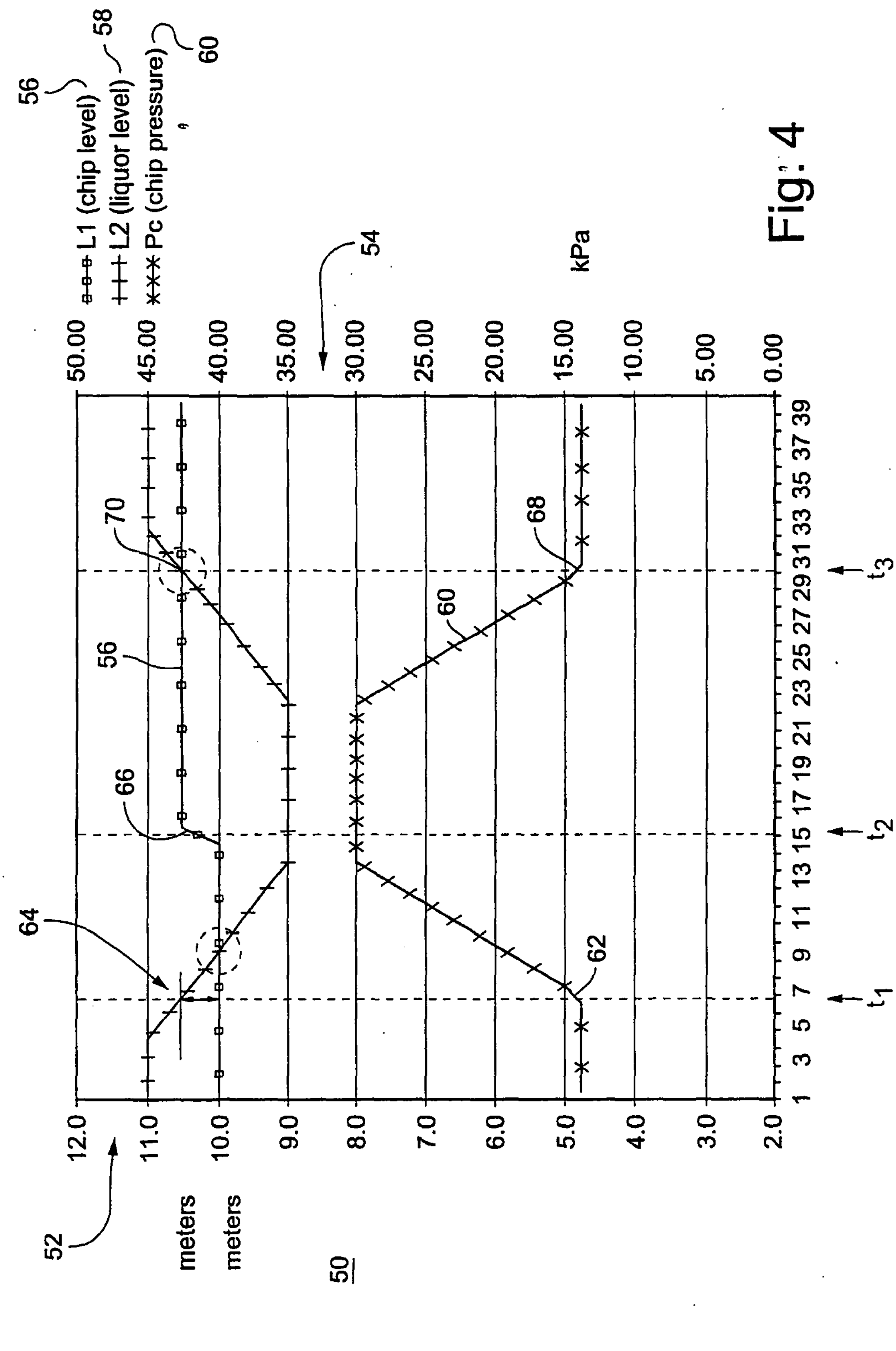
56
58
60
L1 (chip level)
L2 (liquor level)
Pc (chip pressure)
54
kPa
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
meters
meters
52
50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
64
66
56
70
60
68
62
t_1
t_2
t_3

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

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