CONTROL ARRANGEMENT FOR REFINERS WITH TWO REFINING ZONES

Fig 10

In the pulp and paper industry, there is a need to measure process variables spatially directly in the refining zone of refiners, in order to control the process to reduce the variations in energy consumption and pulp quality. This is accomplished by the invention for refiners with two refining zones, separated by a common rotor, and considers a control procedure where the difference between the temperature profiles and/or the pressure profiles obtained from each zone is controlled by changing the dilution water feed rate and/or the plate gap or the hydraulic pressure to each zone. The procedure is also applicable to continuous control of the refining process near machine limits.
CONTROL ARRANGEMENT FOR REFINERS WITH TWO REFINING ZONES

Technical field:

The invention relates to a procedure, where among other measurements, temperature sensors are used directly in the refining zone, controlled by the changes in the dilution water flow rate and plate gap in refiners with two refining zones. The main purpose with the invention is to obtain a more even distribution and consistency in each refining zone. The distribution problem is mainly a result of the difficulties to measure the chip/pulp feed rate and to control the amount of chips/pulp to each refining zone. The procedure also copes with the problem associated with the pulp quality variations in time which can be minimized at the same time as the production of pulp can be increased.

The present invention is applicable in all technical areas where refiners are used, such as pulp and paper industry as well as related industries.

Technical background

Refiners of one sort or another play a central role in the production of high yield pulp and for pre-treatment of fibers in paper-making for the pulp and paper industry and related industries through grinding, for example, thermo-mechanical pulp (TMP) or chemical thermo-mechanical pulp (CTMP) starting from lignin-cellulose material such as wood chips. Two types of refiners are important to mention here; low consistency (LC) refining where the pulp is refined at about 4 per cent consistency (dry content), and high consistency (HC) refining where the consistency is commonly about 40 per cent. LC refining is done in a two-phase system chips/pulp and water, while HC refining has three phases; chips/pulp, water and steam. Refiners are also used in other industrial applications, such as for example manufacturing of wood fiber board.
Most refiners consist of two circular plates, discs, in between which the material to be treated passes from the inner part to the periphery of the plates, see Figure 1. Usually, there is one static refiner plate and one rotating refiner plate, rotating at a very high speed.

The static refiner plate is placed on a stator holder (3), and is pushed towards a rotating one place on a rotor holder (4), electro mechanical or hydraulically (5). The chips or fibers (6) are often fed into the refiners together with the dilution water via the center (7) of the refiner plates and are grinded on its way outward to the periphery (8). The refining zone (9), between the plates (also called segments) has a variable gap (10) along the radius (11) dependent on the design of the plates.

The diameter of the refiner plates differ dependent on size (production capacity) of the refiner and brand. Originally the plates (also called segments 12, 13, see Figure 1 and Figure 2) were cast in one piece, but nowadays they usually consist of a number of modules (forming a disc) that are mounted together on the stator and rotor. The segments can be produced to cover the entire surface from the inner to the outer part of the holders or be divided into one inner part (14) often called "the breaker bar zone" and an outer part (15) called periphery zone.

These segments have grinding patterns (16), with bars (17) and troughs (18) that differ dependent on supplier. The bars can be seen as knives that defibrillate chips or further refine the already produced pulp. The plates wear continuously during the refining process and have to be replaced at intervals of around every 2 months or so. In an HC refiner, fibers, water and steam are also transported in the troughs between the bars. The amount of steam is spatially dependent, which is why both water and steam may exist together with chips/pulp in the refining zone. In an HC refiner water will normally be bound to the fibers. Dependant on the segment design different flow patterns will occur in the refiner. In an LC-refiner no steam is generated and thereby only two phases exist (liquid and pulp).

There are also other types of refiners such as double disc, where both plates rotate counter to each other, or conic refiners. Yet another type is called twin refiners, where there are four refiner plates. A centrally placed rotor has two refiner plates mounted one on either side, and then there are two static refiner plates that are pushed against each other using, for example, hydraulic cylinders thus creating two refining zones.

When refining wood chips or previously refined pulp the refiner plates are typically pushed against each other to obtain a plate gap (10) of approximately 0.2-0.7 mm dependent on what type of refiner is used.
The plate gap is an important control variable and an increased or reduced plate gap is performed by applying an electro mechanical or hydraulic pressure (5) on one or several segments dependent on the type of refiner. With that an axial force is applied on the segments. The force which acting in opposite direction to the axial force consists in HC-refining processes by the forces obtained from the steam generation and the fiber network. In those cases LC-refining is considered the axial force is neutralized by the forces extracted from the increased pressure in the water (liquid) phase and the fiber network. If the plate gap is changed for example 10%, the pulp quality is changed considerably. Therefore, it is important to know the actual plate gap. Today, measurement units for plate gap are provided commercially. Normally, only one plate gap sensor is used to prevent plate clash and not as expected in any control algorithms. Other systems exist as well and one robust system is based on temperature measurements along the radius in the refining zone to visualize the temperature profile (19) alternatively the pressure profile (20) for control purposes, see Figure 3. For LC-refining the pressure is preferred to be measured but for HC-refining the temperature profile will be enough to measure.

When changing the process conditions in plate gap, production and the amount of added dilution water, the temperature is changed which gives an opportunity to control it in different ways. Several temperature- and/or the pressure sensors are often used and can be placed directly in the segments alternatively mounted in a sensor array holder (21) which can be placed between the segments (12 and 13), see Figure 1, Figure 2 and figure 4 as described in EP 0788 407. Usually, the sensor array holder is implemented between two segments in the outer part, see Figure 2.

The design of the segments has proven to be of great importance for characteristics of the temperature profile along the radius. Therefore, it is difficult in advance to decide where the temperature sensors (22) and/or the pressure sensors (22) should be placed in the sensor array holder (21).

According to traditional safety systems for plate clash protection, accelerometers placed on the stator holders (3) and/or the rotor holders (4) are used besides the plate gap sensors.

**Technical problem**

In the literature, extensive materials exist regarding refiner control by using consistency measurements and temperature measurement including safety systems to
prevent plate clash of segments. The safety systems are often built on both hardware (typically accelerometers and plate gap sensors) and software in terms of frequency analyzers and specific functions for limit control et cetera.

The research results indicate that the measurements of vibration on the holders shows deviations from vibrations caused by actual local fluctuation in the fiber pad inside the refining zone, which can be a result of in-homogeneity in the fiber pad or the other phases (water and steam). When considering LC-refining, the in-homogeneity can occur even though there exist only two phases.

The in-homogeneity in the fiber pad is central for the description of the technical problem. If the packing degree of the fiber pad varies locally both spatially and in time this can cause local areas where the spatial temperature alternatively the pressure increase or decrease dependent on if the packing degree increase or decrease. This leads to fluctuations in the pressure distribution in the refining zone which cause non-linear process conditions and thereby a varying residence time for the fibers in the refining zone which can cause bad pulp quality due to fiber cutting. Fiber cutting means that the length of the fibers is shortened too much when they hit the segment bars. The most unwanted situation is obtained when the fiber network is collapsed, i.e. the force related to the fiber network, which can be seen as a repulsive force to the axial force, is reduced drastically which certainly can lead to a plate clash. Therefore, it is of importance to keep the right spatial consistency in the refining zone to prevent phenomena like the fiber pad in-homogeneities.

In the literature, temperature measurements have shown to be an unusual robust technology for HC-refining control. When changing the production, dilution water and the hydraulic pressure the temperature profile is changed dynamically. This dynamic change is visualized in Figure 5a, where a step change in dilution water affect the temperature profile in different ways dependent on where on the radius (11) we consider the process. It is seen that when the dilution water increase, the temperature (23) will decrease before the maximum (24) but increase (25) after the maximum. The reason is that the water added cools down the back-flowing steam at the same time as the steam which is going forward is warmed very fast.

When the production is increased the entire temperature profile (19) is lifted to another level (26), see Figure 5b. The same situation is valid when the plate gap (10) is reduced by increasing for instance the hydraulic pressure.

The non-linearities are affected also by the design of the segments. This can result in different temperature profiles (19, 27) and pressure profiles, see Figure 5c.
The complex pattern of possible conditions has not so far been related to the local change in the refining zone consistency. The reason could be that the focus has been put on the rudimentary enthalpy balance for the entire refining zone without any use of temperature measurements.

All these process conditions, related to an increase in production and dilution water, will affect the active volume inside the refining zone at constant hydraulic pressure and hence affect the plate gap as well as the temperature and/or the pressure profile. This will result in a change in the fibers residence time which affect the fluctuations in the refining zone and finally the pulp quality. The process conditions can also drive the refiner into situations where another operating point is obtained which by safety reasons are forbidden due to the risk for damage. These forbidden areas are difficult to predict on beforehand with present technology.

In a research project a new theoretical physical model has been documented ("Refining models for control purposes" (2008), Anders Karlström, Karin Eriksson, David Sikter and Mattias Gustavsson, Nordic Pulp and Paper journal). The model, describes HC-refining and it is supposed that the temperature and/or the pressure are measured along the radius of a segment to span the material and energy balances in the refiners and thereby make it possible to estimate the plate gap. The main difference compared with earlier rudimentary trials to describe the physics of the grinding processes is that the model estimates both the reversible thermodynamic work and the irreversible defibration work applied on the fiber network where the shear forces have a central position when iterating to find the right plate gap. Thereby, the model is described from an entropy perspective instead of an enthalpy based approach which does not take into account the shear between the fibers, flocks, water and the segments. In this model it is assumed that the production rate is possible to measure which indeed is hard to prove due to for example the fluctuations in raw material density et cetera. Instead, in real processes the production is an estimate based on assumed consistency and speed rate of the refiner load conveyers and this cause problems in most control concepts where the production is assumed to be measured. The model is of course a simplification but it has been useful for research purposes.

In those cases where the refiners are constructed with two refining zones, i.e. refiners normally called Twin refiners, another problem occurs as the amount of chips or pulp distributed to each refining zone is unknown. Consequently, in those situations where two or more serially linked Twin refiners constitute the production line, the final pulp quality is affected and can vary considerably if the deviations in consistency between the two refining zones are not evened out.
Hence, the problem is that the distributed consistency along the radius in the refining zone is not possible to measure which means that other solutions of the problem must be used. This can be expressed as follows:

In those cases where refiners with two refining zones, divided by a rotor, are considered asymmetric temperature profiles can be obtained, see Figure 6. Usually these refining zones are called Front Side (28) and Drive Side (29). These two sides are below referred to as FS and DS, respectively.

The asymmetric temperature profiles can be a consequence of:

1. two different plate gaps, caused by the difficulties to position the rotor, but the same chip or pulp feed rate. This result in a situation where the temperature profiles are displaced between themselves, see Figure 6a;
2. a situation where the chips to the primary refiner or the pulp to the secondary refiner are fed (unintentionally) differently to the FS and DS. This result in an uneven distribution of the chips or the pulp which is reflected in the shape of the temperature profile, see Figure 6b;
3. two different plate gaps, caused by a problem with the positioning of the rotor but with different chip or pulp feed rates. This result in a displacement of the temperature profile according to Figure 6c;
4. different fiber packing degrees dependent where in the refining zone the pulp occurs. This can be a consequence of a random situation where the fibers in the refining zone are distributed differently during the start up procedure of the refiners.

Summary of the invention

The aim of the present invention is to remedy one or more of the above mentioned problems. In a first aspect of the invention, this and other aims are obtained by a method according to claim 1.

The invention is based on a procedure where robust temperature- and/or pressure measurements in combination with available signals from the process, to control the amount of added dilution water to each refining zone and finally the hydraulic pressure applied on each stator on the Front Side (FS) and Drive Side (DS).

As the temperature profiles in each refining zone is desired to converge to each other, instead of the described situation in Figure 6b, the dilution water must be controlled in
another way compared with the situation faced today. The following procedure is therefore a solution of the problem.

1. By measuring and comparing the load on the conveyers (feed screws) to each refining zone, i.e. FS and DS respectively, an indication is obtained how the distribution of chips or pulp to each refining zone looks like in a relative perspective. If the load for the feed screw on the FS is higher compared with the one on the DS it is possible to assume that more pulp is present in the FS feed screw and vice versa, see Figure 7. This of course requires similar motors and mechanical construction for the screws which sometimes is hard to assume.

2. As a complement to the studies of the load conveyers, the vibrations on the stators FS and DS respectively can be measured using accelerometers. If the vibration, for instance, is higher on the DS less pulp is fed on that side which has not been known earlier. Instead it has been believed that large vibrations always is related to high fiber packing degree of the pulp in the refining zone.

3. At the same dilution water feed rate to each side i.e. the FS and DS, and high load on the feed screw to the FS a too high consistency is obtained compared with the DS. This can result in the situation described in Figure 6b at the same plate gap. If we know that more pulp is fed to the FS it is possible to compensate for that by controlling the dilution water feed rate to each refining zone in order to obtain the situation described in Figure 8. In this specific case, the dilution water is increased to the FS. It is also possible to decrease the dilution water feed rate to the DS but this can sometimes cause in-homogeneous refining. This can however, be followed by analyzing the inner temperature variations as this part of the refining zone correlates to pumping effects caused by the in-homogeneities which also can be captured by analyzing the measurements from the accelerometers on each side. Sometimes it is preferable to change the dilution water flow rate in opposite directions to the refining zones.

4. The remaining difference between the temperature profiles on FS (28) and DS (29) respectively, as seen in Figure 8, can thereafter be adjusted by reducing the hydraulic pressure on FS alternatively increase the hydraulic pressure on the DS in order to obtain the situation described in Figure 9. By using the same arguments as above it is favorably to make the necessary changes on FS.

5. It is concluded that this procedure will result in a more symmetric distribution of pulp in the refining zone and thereby a similar consistency on the FS and DS respectively. This will also result in a similar residence time for the fibers in the refining zone and thereby a more homogeneous pulp quality. The relative local consistency in the refining zone can preferably be estimated by using the algorithms described in the paper "Refining models for control purposes", 


Nordic Pulp and Paper Journal, 2008 but this is not required for the solution described here.

6. If the consistency is controlled in the blow line, out from the refiners, normally the same control action is performed on the dilution water controller. In present solution of the problem a quotient between the dilution water to FS and DS respectively can be introduced. This quotient can be maintained over long periods and also be slightly modified to get a good balance between the FS and DS. Thereby, both temperature profiles are changed in a similar way. In those cases where the maximum temperature is controlled by the hydraulic pressure, this control algorithm will adjust the temperature profiles to the right level. No problems with "wind up" will occur since this control loop is not affecting the consistency to any appreciable account, see further discussion in the paper "Multi-rate optimal control of the TMP-refining processes, Anders Karlstrom and Alf Isaksson, IMPC conference 2009.

7. If the pressure- or the temperature profile is not measured spatially in the refining zone the distribution of pulp to each zone can only be controlled approximately by using the information from the load conveyers and the accelerometers described in item 1 and item 2 above. This can be seen as the last alternative when all sensors mounted in the refining zone are damaged. However, no such control concepts have been implemented in refining processes.

8. The complete procedure is preferably linked to the information about the valve opening for the dilution water as this information is directly related to the back-pressure on FS and DS refining zones, respectively. If the piping is equal on each side and the valves are identical, a large opening degree corresponds to a high back-pressure and consequently a larger volume of pulp in the refining zone.

9. At the same dilution water flow rate to FS and DS, it is sometimes possible that a larger load on the feed screw results in a higher consistency compared with the one on the DS and this can result in a situation comparable with the one described in Figure 6c. This is a consequence of different plate gaps on FS and DS, respectively. In those cases the maximum temperature will be displaced forward the segment periphery. This situation is much more difficult to control compared with the one described in item 2 above. This will result in higher vibration on DS as less pulp will be fed to this side. In this specific case the hydraulic pressure can be increased on FS and thereafter we have to compensate and control the dilution water flow rate to each refining zone to get the same consistency.
In Figure 10, a schematic controller for the process is shown. The unit (41) consists of a computer or similar electronic devices which are fed with the difference between the requested temperature profile vector (set point) (42) and the measured temperature profile vector (process value) from each refining zone (10). In the control unit (41) the difference vector is handled together with the algorithms for estimation of the distribution of chips or pulp to the refining zones by comparing the motor loads on the feed screws and/or the opening degree for the dilution water valves in combination with the difference between the temperature profiles on FS (28) and DS (29) respectively. The difference and distribution is thereafter used for controlling the dilution water flow rate (43) and the hydraulic pressure (5) to each zone. In this unit, an acceptable distribution function is implemented (like the maximum and minimum difference in the distribution of the temperature profiles and/or the motor load on the feed screws to FS and DS).

From the process (44) the process variables (45), like the temperature profile and pressure profile vectors, are measured intermittently with high sampling rate in a measurement unit (47) required for control. The pulp is obtained from the position called (48).

In those cases where reliable plate gap measurement units are available, the above mentioned control concept can also include such devices as they can replace the hydraulic pressure and thereby give an understanding of the actual volume in the refining zone. This information will also correlate to the variations in the load of the feed screws to FS and DS which even more strengthen the concept.

Hence, the main purpose of the invention is to describe a procedure with high accuracy which can present an on-line based controller for the temperature profiles in refiners with two refining zones by using the knowledge of the chip and pulp distribution in each refining zone and thereby control the dilution water feed rate to each refining zone. The invention is thereby based on the assumption that the temperature- and/or the pressure profile can be measure in each zone. Different types of functions can reflect the distribution between the FS and DS. It should be noted that while the above describes exemplifying embodiments of the invention, there are several variations and modifications which may be made to the disclosed solution without departing from the scope of the present invention as defined in the appended claims.
Brief description of the drawings:

Figure 1: Section of a stationary disc (circular plates) which is pushed towards a rotating disc.

Figure 2: Two segments where the sensor array holder, used for temperature- and/or pressure measurements, is placed in between.

Figure 3: Temperature profile and pressure profile as a function of the radius in the refining zone.

Figure 4: The sensor array holder with the sensors placed along the surface.

Figure 5a: The shape of the temperature profile before and after an increase in the dilution water feed rate.

Figure 5b: The shape of the temperature profile before and after an increase in production.

Figure 5c: The shape of the temperature profile before and after a change in segments.

Figure 6a: The temperature profiles for a case with different plate gaps but with the same amount of chips or pulp to the refining zones.

Figure 6b: The temperature profiles for a case with asymmetric distribution of chips or pulp but with the same dilution water flow rate to the refining zones.

Figure 6c: The temperature profiles for a case with asymmetric distribution of chips or pulp but with different plate gaps and the same dilution water feed rate to the refining zones.

Figure 7: Load for the feed screws for a refiner with two refining zones.

Figure 8: Temperature profiles for a case with asymmetric distribution of chips or pulp to the refining zones. In this case, the dilution water feed rate to one refining zone is modified to get similar consistency to the corresponding refining zone.

Figure 9: Temperature profiles for a case with asymmetric distribution of chips or pulp to the refining zones according to Figure 8 where the hydraulic pressure is used to even out the difference between the two refining zones.
Figure 10: Schematic description of how the different temperature profiles are controlled by using the dilution water feed rate and hydraulic pressure, alternatively the plate gap, to get similar temperature profiles and thereby similar consistency in the different refining zones.
Claims

1 Arrangement for control of the grinding process in refiners with a first and a second refining zone, where the arrangement comprise at least one series of sensors (22) positioned on a series of distances from a refiners Centrum in the first refining zone and a second series of sensors (22), positioned along the active radius on different distances from a refiners Centrum in the other refining zone, where the series of sensors are arranged to measure at least one of the two process variables pressure or the temperature, where the arrangement to that also comprise a first and a second measurement device for measuring the motor load of the chip or pulp feeding system to the first and the second refining zone, and further a first and a second device for controlling the dilution water to the first and second refining zone, characterized in that the arrangement comprise a control arrangement (41) which receives measurements at least from the two series of sensors (22) and/or the two measurement devices for measuring the motor load of the chips or pulp feeding units, where the control arrangement is set to at least control the first and the second dilution water controller so that the difference between the measured values from the two series of sensors (22) is minimized.

2 Arrangement according to claim 1, characterized in that it further comprise a first and a second pressure controller which controls the applied axial pressure on the refining segments in the first and the second refining zone, where the control arrangement (41) to that also control at least one of the pressure controllers in order to minimize the difference between the measured values from the two series of sensors (22).

3 Arrangement according to claim 1-2, characterized in that the arrangement further comprise a consistency sensor which measure the consistency in the outlet from the refiners and/or an estimated consistency from each refining zone where the control arrangement (41) receives measurements from the consistency sensor for use in the control process.
Arrangement according to claim 1-3, characterized in that the arrangement further comprise a plate gap sensor in each refining zone which measure the plate gap between the stator and the rotor and where the control arrangement (41) receives measurements from the plate gap sensor for use in the control process.

Arrangement according to claim 1-4, characterized in that the arrangement further comprise measurements of the valve opening of the dilution water devices to the first and second refining zone and where the control arrangement (41) receives measurements from the dilution water valves for use in the control process.

Arrangement according to claim 1-5, characterized in that the arrangement further comprise measurements of the vibrations related to the first and the second refining zone and where the control arrangement (41) receives measurements from accelerometers for use in the control process.
## A. CLASSIFICATION OF SUBJECT MATTER

**IPC:** see extra sheet

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

## B. FIELDS SEARCHED

**IPC:** D21D, D21B

Minimum documentation searched (classification system followed by classification symbols)

**IPC:** E21D, E21B

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

SE, DK, FI, NO classes as above

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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See patent family annex.

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**Date of the actual completion of the international search**

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### INTERNATIONAL SEARCH REPORT

**International application No.**

**PCT/SE2010/000174**

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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International patent classification (IPC)
D21D 1/00 (2006.01)
D21B 1/14 (2006.01)
D21D 1/30 (2006.01)

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