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CONTROL OF THE REFINING PROCESS

The practical solution proposed by BTG

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Abstract

These prerequisites must be fulfilled if the refining process is to be stabilized:

1. Identification of all process variables.
2. Reconsideration of all control and process circuits.
3. Automation of the process based on information delivered by sensors.

Required refining Analyzer properties are:

a) Compatibility for effective control, i.e. availability, repeatability, sensivity, adaptability,
b) In-line installation,
c) Defendable installation and operation costs,
d) Not limited with regard to qualify of supplies.

The DRT-90 Analyzermeets these requirements by:

-- Its measuring principle.
-- Its way of determining the refining degree.
-- Its measuring cycle.
-- Its correlation with Schopper-Riegler (SR) and Canadian Standard Freeness (CSF).
-- The fact that it can provide a second drainage rate measurement on the same sample, after automatic washing out of fines and fillers in the analyzer (i.e. on long fiber functions only) which gives complementary information on the properties of the retined pulp.

Possibility to translate DRT index into ^{0}SR.

Refining control strategy.

Refining and occurring disturbances.

Automatic control of the refining process.

Keywords

Refining — Control systems — Sensors — Freeness —Degree of beating- On-line measurement — Automatic control —Drainage.

Introduction

Empiricism, the practice of relying on observation and experiment is neither acceptable nor accepted in modern pulp and paper production. The latter is subject to constraints with regard to productivity, raw material and energetic economy. Hence quality is to be achieved within narrow limits.

Refining has, like so manyother processes, developed from an art into a technique. Cooperation between papermakers, research institutions and equipment manufacturers has permitted to optimize the performance of refiners as to development of fiber propertries with regrd to papermaking and energy consumption. We must be aware, however, that the refining process is still subject to all restraints of production and often remains the least mastered process step in papermaking. The reasons are variations of the properties of the raw material, machine failures, state of the refining equipment, etc.

If we assume a stable process (fig. 1a), a simple determination of ^{0}SR per batch may be sufficient. But, what will happen to quality and productivity when the process is disturbed (fig. 1b), broke entailing even more broke?

Seen from our angle, the solution is to be found at three levels, following this hierarchy:

1. Identify the variables by the installation of appropriate sensors is the Refining Analyzer. Here, an indispensible tool for mastery of the refining process.
2. Chase down disturbances by reviewing of loops and circuits as well as reviewing of the methods of process conduct based on information supplied by the sensors. This sometimes leads to the need for replacement of equipment that does not reach the required performance (badly adapted pumps, poorly performing consistency sensors, etc.) or, simply, to the setting up of different lead values (setpoints) for the operators.
3. Automation of the process based on information supplied by the sensors. Closed loop opertion yields other information on the system and generally enables, besides the sought-after stability, to achieve a further step in the direction of full process knowledge. As a matter of fact, it is easier to induce controlled variations and to observe their influences if this is done on a stabilized, controlled process.

The Refining Analyzer—Specifications

Precise objectives were given to the R&D group of BTG (then Eur-Control) with regard to the development of the instrument that became the **DRT Refining Analyzer:**

The primary requirement was to develop a sensor far superior to the one of the preceeding generation (-1983) and to all other present on the market, and which is

1. **Suitable for refining control, hence has a high degree of:**
   - (a) availability (low and easy maintenance),
   - (b) repeatability (no influence by normal disturbances),
   - (c) sensitivity (no signal noise super-imposed on measurement, hence enabling to operate on high signal gain).
   - (d) adaptability (to be used on all types of pulp and at all refining levels, i.e. from 10°SR to 97°SR);
2. **Suitable for in-line installation,** without bypass subject to clogging, but at the same time serviceable without process interruption.
3. Be of an installed cost **moderate enough** to permit the automation of a maximum number of refiners, even in production units of moderate size;
4. Be free of constraining limits with regard to supplies.

The measuring instrument resulting from this research was marketed from 1985 on, under the name of DRT.

A second generation, the DRT-90, incorporating several improvements (simplification of operation and maintenance) was introduced by September 1986. These improvements can be transferred by the company's after sales service to the majority of units of the first generation, thus increasing the possibilities offered by these instruments.

We think that it can be said that the objectives given to the R&D group were attained to the order of 9/10, the only point that remains is the question of the quality of the supply water required by the instrument. It is very difficult, indeed, to find clean water in a pulp or paper mill!

At the end of 1987 more than 30 DRT units were sold in France. More than half are utilized for control according to the control strategies described in the following text.

The DRT-90-operating principle

The refining analyzer DRT-90 (fig. 2) consists of two parts:

-- the sensor part installed on the pulp line by means of a welded stud,

-- the electronics unit equipped with a micro-processor governing the functions of the sensor, the processing of the output signals and production of alarms.

the utilization of a micro-processor provides total flexibility in the adaptation of the measuring instrument to all conditions encountered with regard to consistency, degree of refining, etc.

Consequently, the DRT-90 can be used on free (panel) pulp (10-SR) or drawing paper pulp (< 95°SR) at consistencies from 0.5 to 7%, and even, with a slightly modified instrument, for measurement of TMP and CTMP pulps at 75°C ahead of the latency chest.

The measurement is effectuated according to a programmable cycle, memorized and governed by the micro-processor. The cycle consists of the following phases:

Sampling

A hollow piston sampling valve takes a sample of approx. 0.11 of pulp from the center of the pulp line.

Dilution and mixing

The sample is diluted to 7-10 times (depending upon the ratio between its volume and the mixing chamber volume).

The consistency now being between 0.5 and 0.8%, the sample is homogenized for 35 seconds (programmable) ahead of the measurement. This phase produces two main effects:

(a) It ensures excellent repeatability of the measurements by the elimination of the influences of flocculation — a very important factor if the instrument is to be used for control.

(b) The reduction of the temperature variations of the sample, within a ratio of 1/7 to 1/10 reduces the influence of the latter on measurement (the viscosity of the water intervenes in the drainage rate formula). The flushing water temperature is assumed as being stable except for seasonal variations.

Pre-drainage

A fiber mat is formed on the screen, Pre-drainage is effected at constant pressure provided by a constant overflow.

Contrary to the Schopper-Riegler instrument, the measurement in the DRT starts only when the drainage velocity is stabilized, i.e. after 35-45 seconds (programmable) see fig. 4.

Here, too, two benefits can be found:

(a) Reduction of the influence of screen cleanliness. During the entire measuring phase, screen resistance is negligible compared to the one of the pad of fibers.

(b) Reduction of the influence of the fines and of original sample cosistency.

Measurement

Duration: 15 to 120 seconds, depending on freeness of the pulp.

During pre-drainage, the water leaves to waste (fig. 3) but in the measuring phase the filtrate is led into a measuring chamber containing three electrodes with which the instrument can determine the time required for production of a given volume of filtrate.

The time measurement, i.e. the time required to obtain the set filtrate volume, is converted into an analog signal of 4-20 mA. based on programmable parameters for zero offset, gain and (optional) digital filtering.

The first measurement represents the drainability of the entire sample including long fibers, fines and filers, i.e. the '1st DRT signal' (unwashed signal).

Flushing

Counter-current flushing of the screen removes the pad of fibers and restores the mixing chamber to its initial condition, filled with water. The adjustable flushing time (30-40 s) enables to extend the intervals of manual screen cleaning from 15 days to 3 months, depending on the type of refining process.

A second measuring cycle on the same sample can be programmed. In this cycle the sample is stirred in water, then 'washed,' during the mixing phase, in order to eliminate the fines. The second measurement on the pad of washed fibers results in a signal that is different from the first, providing complementary information as to the state of the pulp. This index is called the "2nd DRT signlal" or "washed" singal.

Today still, relatively few pulp makers make use of this complementary posibility. We think, however, that this measurement offers an interesting research prospect that can be used more efficiently once the control system is stabilized thanks to the automatic control which is available through the "1st DRT signal" (unwashed).

DRT Index and SR

Numerous test reports are available, both from our laboratories and from DRT users. These tests were carried out while DRT-users were setting up their control straegies (tackle tests, pulp tests, comparison of separate refining of long and short fibers).

The experience gained from this research, can be summarized as follows.

- — The DRT signal (first) correlates well with °SR (CSF) for a given pulp and type of refiner. This correlation is maintained over a long period of time.
- — It is possible, without excessive signal noise on the measurement, to adjust the DRT for a range extending between 15 and 25°SR.
- — On different pulps, DRT and Schopper measurements may differ quite sensibly, e.g. 5 to 8°SR for the same DRT signal on long fibers of different origin. This is due to the measuring principle used by the DRT which privileges the influence of the specific fiber surface area because the pad is formed ahead of and not during measurement.
- — Influence exerted by line consistency is relatively weak, not to say negligible within normal variations, i.e. inferior to +/- 5%.

- — The influence of the line pulp temperature is reduced due to the dilution of the sample. It is necessary, however, to make sure that the instrument is supplied with filtered water of stable temperature.
- — Line pressure and flow have no influence whatsoever on the measurment.
- — The influence of latency with TMP at the refiner outlet can be eliminated in the DRT-92 analyzer by a 3 min. hot treatment of the pulp in the measuring chamber of the instrument (see also item 2, bibliography).
- — The influence of fines, carried by the dilution water in varying proportion or produced in the refiner can be eliminated from the measured value by making use of the second measuring cycle and signal of the DRT.

Hence, the DRT index constitutes a reliable means to determine the state of refining of the pulp. This leads obviously to deduct its value for automtic The control of refining process, a further step towards automation of stock preparation.

Refining control strategy

Different levels of automatic refining control are utilized at present. From the most rudimentary to the most complex, even if we exclude manual control based on current indication (ammeter watching):

1. **Automatic regulation of intensity** and sometimes of power. At this elementary level of control, the experience and alertness of the operators is of extreme importance. They have guidelines: trough-water level, vacuum at the suction box, measurement of porosity or transparency, if in use.

   The utilization of the measurement of power in place of intensity measurement does not present much improvement, with the exception, perhaps, of a wider apparent control range. In fact, as it varies very much with the refiner load, the idle intensity is often 60% of maximum intensity.

2. **Specific energy (power) control.** The most difficult to compensate disturbances for the opertors are fast changes due to production variations. The contro of specific energy input has become quite a standard practice. We will see further on that specific energy control presnts only a partial solution for refining control but it has its place in the global control strategy based on the refining index.

3. **Automatic control by refining Index:** this ultimate stage of refining automation, based on the refining index supplied by the DRT, can be handled in different modes.

Inasmuch as the DRT measurement is updated every 2-3 min., it is sensical to regulate by intensity/power specific energy or even flow. In the following text we will consider only specific energy control which is the most used and best adapted to refiners operating in series or parallel but also to single refiners that must adapt to variations in production.

Refining and its disturbances

The curves in fig. 5 schematically show the which parameters determine the power required for achieving a given refining index (°SR/CSF or °DRT).

Type of pulp: the type of pulp or, in case of the refining of mixed pulp, its composition, is a determining factor with regard to the specific energy demand. In an integrated mill, locally produced pulp (transferred to refining in suspension), may require 40% less energy than bale-supplied pulp.

Initial refining Index: the unavoidable recirculation of broke, minimal flow circulation through the refiners, or variations due to pre-refining, show different energy demands if a stable final refining index is to be achieved.

Production variations can, in theory, be compensated by the use of specific energy control. Useful refining power must be proportional to production, i.e. to the product of flow x consistency (mass flow).

It is easy to precisely measure the parameters entering the formula: energy, flow and consistency.

$$\text{Specifific energy (kWh/t)} = \frac{(W-W_o)X100}{CxF}$$

where:

W=total energy in kW
W_o=idle energy in kW
C=consistency in %
F=flow in m^3/h

On the other hand, the parameter Wo can only be determined empirically and would be highly overvalued if the idle energy (refiner tackle open) is to be taken as a base. It further varies with the operating conditions. Generally, one must be satisfied with the selection of a random value which, when production is varied, doesn't lead to a notable change of the refining index.

Incidentally, if the parameter consistency is entered for more scientific severity, it can be observed that consistency variations translate into a different refining mode, hence must be compensated ahead of the refiners.

State of the Refiner

This point comprises factors that normally do not evolve rapidly

-- the type of refiner.

-- the type of tackle used.

-- the state of wear of the tackle.

A question of prime importance is: "what happens with specific energy control when the tackle is replaced?"

Automatic refining control

All these observations emphasize the interest in automtic control of refining according to the principle shown in fig. 6.

The measured refining index (the DRT-90 signal) is compared to the operator set point in the refining index controller (QIC) the output of which acts on the external set point of the specific energy controller (EsIC).

This controller adjusts the position of the refiner tackle by means of the servomotor. the entity servomotor/refiner, however, behaves with regrd to the refining index of the pulp like a very imperfect control component. It could be compared to a control valve where the opening of which below 40% wouldn't produce any effect any more and which would present significant play and hysterisis.

The recommended cascade solution is destined to remedy to these imperfections. In fact, it would be difficult with such conditions to control the opening/closing of the refiner tackle directly via the refining index controller, even if stable production is assumed.

Normally, the calculating and ancillary functions that result from the above observations would be incorporated in the specific energy controller (EsIC) unless there is a centralized control/adjustment system.

The minimum functions are the following:

- Specific energy calculation: $E = \frac{(W-W)}{(CxF)}$

- Specific energy control with output by time modulated impulsions, adjustable dead band and pulse length frequency.

- Low power (W) limitation to a value slightly higher than the power requirement at normal flow and with 'open' tackle.

- High power limitation.
- Automatic reset to specific energy control when the measurement of refining index is not confirmed (DRT in alarm position).
- Automatic change-over of specific energy control to external set-point (without intervention) if measurement is valid but with:
- a time lag corresponding to at least 2 refining analyser cycles (5 min).

As the refining analyzer function is interlocked by the pump or refiner, the measurement is validated only when the installation is operating normally.

For the set-up of the control installation, simultaneous recording of the parameters energy, flow and refining index was found to be very useful.

Discussion of results:

The implementation of automatic refining control on the system described in the introduction to this paper would have produced deceiving results unless it were preceeded by the already mentioned measures:

- Identification of the variables and review of the pulp loop. This was actually the strategic adopted prior to the automation phase that is now being implemented.

Automation of systems stable by nature can be achieved without difficulty. Two examples of the influence of automatic control:

Power control on 'short fibers'

Fig. 7a is a recording of power, flow and DRT index on a 'short fiber' system and of a duration of 4 hours during which power control was in action. This recording permits to note the perfect reproducibility of the DRT measurement when there is no dampening. Also the symmetry of the flow recording and of the one of the DRT index can be noted, evidence that, for this short period of time, a specific energy control would have been sufficient for compensation of the only active disturbance, i.e. flow variation. On long term, however, refining index control has proved extremely useful.

Refining control and 'long fibers'

Fig. 7b shows a similar recording on a 'long fiber' system but with refining control. We can note here the stability of the DRT index but also the important variations of flow and power which trigger the appearance of disturbances other than flow but which are effectively corrected by the control system.

Conclusion

We believe that we were able to demonstrate in this paper that there are reliable means to measure and automatically control the refining process. The setting up of these control tools is relatively easy and their utilization will without doubt increase in the coming years. They will enable considerable improvements in:

-- quality

-- productivity

-- economic use of energy

-- ess wear of refining tackle

-- ease of operation

Automatic refining control can either be integrated into existing control systems or be set up independently of the latter thanks to the availability of programmable controllers incorporating the required logical and computation functions.

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