TAMPERE UNIVERSITY OF TECHNOLOGY

JANNE VIDERHOLM

CONSISTENCY DISTURBANCES DUE TO DISC FILTER AND THEIR CONTROL

Master of Science Thesis

Examiner: Professor Risto Ritala
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Diplomityössä tutkittiin kiekkosuotimen aiheuttamia sakeus- ja tuhkasakeushäiriöitä sekä niiden hallintaa. Tasalaatuisen massan syöttö paperikoneen perälaatikolle on tärkeää, sillä häiriöt siellä näkyvät paperin laadussa. Kiekkosuotimen on sanottu olevan yksi suurimmista näiden häiriöiden lähteistä, varsinkin tuhkan osalta. Massankäsittelyssä säiliöt vaimentavat korkeataajuisia häiriöitä ja säädöt matalataajuisia häiriöitä.

Kaikki tutkimuksissa käytetyt mittaustiedot ovat peräisin oikealta paperitehtaalta. Kohdetehtaalla on kaksi kiekkosuodinta toimimassa rinnakkain. Dataa kerättiin 0.2 Hz näytetaajuudella. Analyysit suoritettiin laskemalla ja simuloimalla Matlab/Simulink ympäristössä. Häiriöiden suuruuksien vertailussa käytettiin hyväksi variaatiokerrointa (COV) jolloin eri yksiköllisten suureiden vertailu oli mahdollista.

Kaksi KajaaniRM3™ mittaria asennettiin kohdetehtaalle mittaamaan suodosmassan tuhkapitoisuutta sekä nollaveden sakeutta ja tuhkasakeutta. RM3 mittaa vain 2% sakeuteen asti, joten suodosmassa oli laimennettava ennen mittausta. Laimennuksen jälkeen kokonaissakeuden ja tuhkasakeuden suhde pysyi samana, jolloin tuhkaosuus saatiin laskettua. Työssä käytiin läpi eri tapoja toteuttaa säädöt kuidun talteenoton alueella. Kaksi erilaista säätötapaa esiteltiin tarkemmin: nykyinen käytäntö kohdetehtaalla ja Optifeed-konseptin mukainen säätötapa.

Mittauksia tutkiessa huomattiin, että kohdetehtaalla oli suodosmassan virtauksen säädön asetusarvo otettu suhteessa apumassan virtauksen mittaukseen. Apumassan virtauksessa oli suurta vaihtelua ja tämä vaihtelu johdettiin suoraan säädön välityksellä suodosmassan virtaukseen. Apumassan virtauksessa kiekkosuodin 1:lle todettiin myös jumittuva virtauksensäätöventtiili, joka vaihdettiin. Suodosmassan virtauksen asetusarvolaskennassa käytetty apumassan virtausmittaus korvattiin apumassan virtauksen asetusarvolla, jolloin

häiriöt virtauksessa vähenivät neljäsosaan aikaisemmasta. Myös häiriöt suodosmassan sakeudessa vähenivät muutosten johdosta 60 %.

Merkkiainekokeita suoritettiin kohdetehtaalla säiliöiden sekoitusolosuhteiden selvittämiseksi. Tutkitut säiliöt olivat suodosmassasäiliö ja sekoitussäiliö. Merkkiainekokeissa mitatut vasteet sovitettiin kolmeen säiliömalliin: ensimmäisen asteen malliin, epäideaaliseen säiliömalliin sekä malliin, jossa epäideaalinen säiliömalli on sarjassa ensimmäisen asteen mallin kanssa. Vasteiden sovituksessa minimoitiin neliöityä kustannusfunktiota mitatun vasteen ja säiliölle simuloidun vasteen välillä. Myös täyteaineen kulkeutumista kiekkosuotimen läpi tutkittiin merkkiainekokeilla.

Säiliöiden merkkiainekokeet osoittivat, että säiliöissä on paljon epäideaalisuuksia, kuten säiliöön sisään menevän virtauksen kanavoituminen suoraan ulostuloon kulkeutumatta sekoitusalueen läpi. Sekoitussäiliössä noin 10% säiliöön sisään menevästä virtauksesta kulkeutuu lähes sekoittumatta suoraan ulostuloon ja suodosmassasäiliössä kiekkosuodin 2:lta tulevasta virtauksesta tämä osuus on jopa noin 20%. Säiliöissä todettiin myös suuria pysähtyneitä alueita, jotka eivät sekoittuneet. Sekoitussäiliössä ideaalisesti sekoittuneen alueen osuudeksi saatiin noin 83-87% ja suodosmassasäiliössä tämä osuus oli vielä huomattavasti pienempi. Täten säiliöiden epäideaalisia malleja tulisi käyttää kun tutkitaan niiden häiriönvaimennuskykyä. Suodosmassasäiliössä todettiin olevan pitkiä viiveitä, jotka viittaisivat siihen, että säiliön sisäänmenon syöttö ei osu sekoitusalueelle. Merkkiainekokeilla myös osoitettiin, että normaalissa ajotilanteessa kohdetehtaalla puolet kiekkosuotimelle nollaveden mukana tulevasta täyteaineesta kulkeutuu suodosmassaan ja puolet talteen otettuihin suodosvesiin.

Analyysit osoittivat, että normaalissa ajotilanteessa kohdetehtaalla 38% konemassan täyteaineesta tulee suodosmassasta ja täten siis kiekkosuotimilta. Tutkimukset osoittivat myös, että häiriöt suodosmassan tuhkasakeudessa ovat suuremmat kuin häiriöt suodosmassan kuitusakeudessa. Suodosmassan sakeusmittaus näyttäisi, että sakeus pysyy 0,1% putkessa, mutta kohdetehtaalla oleva sakeusmittari ei havaitse täyteainetta ja täten todellinen vaihtelu on arviolta noin 4,5 kertaa suurempaa. Nollaveden ja suodosmassan sakeuden ja tuhkaosuuden välillä katsottujen ristikorrelaatioiden ja koherenssien perusteella voidaan päätellä, että luotettavaa taajuusvastetta näiden välille ei voida laskea joten siirtofunktion estimointi ei ole tarpeellista. Koherenssien estimoinnissa tarvittavien tehospektrien estimaattien laskenta toteutettiin käyttämällä Welchin menetelmää 50 prosentin limityksellä ja ikkunafunktiona käytettiin Blackman-Harris ikkunaa.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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The objective of this thesis was to study total consistency and ash consistency disturbances caused by disc filter and controlling of these disturbances. Stable thick stock mass flow is important in papermaking process and the consistency variations in the incoming stock to paper machine headbox can be seen in the quality of the paper. Disc filter is said to be one of the dominant disturbance sources, in particular regarding the ash consistency.

All the data used in the analyses was collected from a real paper mill. Two KajaaniRM3 analyzers were installed at the case mill to measure the ash content of recovered stock and total and ash consistency of white water. Tracer tests were executed to study the mixing dynamics of the recovered stock chest and blend chest and to study the filler distribution in disc filter.

Different methods to control the fibre recovery area were discussed. Two methods were described: current practice at the case mill and Optifeed concept. The analyses on the mixing dynamics of the chests showed that non-ideal phenomena such as channeling and stagnant zones exist in the chests. Therefore the non-ideal chest models should be preferred when studying the disturbance attenuation of industrial chests. Tracer tests showed that half of the filler in white water going to the disc filter propagates to the recovered stock and the other half goes to the filtrated waters during normal operation at the case mill.

Analyses showed that 38% of the filler in the machine stock comes from the disc filters at the case mill during normal operation and that the variation in the recovered stock ash is bigger than in the fibre. The recovered stock consistency measurement showed that the variation was in the limit of 0.1% peak to peak but it is insensitive to filler content and thus the real variation bigger. Studies also showed that reliable frequency response can’t be estimated between the white water and recovered stock.

PREFACE

This thesis work was carried out for the Tampere University of Technology at the Department of Automation Science and Engineering. The work was done in a co-operation with UPM-Kymmene.

I wish to express my gratitude to my advisors Professor Risto Ritala, Mr. Taisto Huhtelin and Mr. Mika Korpela for their valuable advice and support during the work. For Taisto I wish pleasant and relaxed retirement days. I wish to thank Mr. Timo Rousu for his valuable help in organizing the tracer tests and Mr. Jari Mikkonen for all the advice and help he provided. I would also like to thank the staff of the Department of Automation Science and Engineering and the staff of UPM-Kymmene.

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Tampere, 23.3.2010

Janne Viderholm

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List of abbreviations, notations and symbols

Abbreviations

PGW	Pressurized groundwood pulp
PID-controller	Proportional-integral-derivative controller
SC	Super calendered
TMP	Thermo mechanical pulp

Notations

c_{ash}	Ash consistency, %, g/l
c_{tot}	Total consistency, %, g/l
$c_{tot,BTG}$	Total consistency measured with BTG shear force meter
$V_{fully\ mixed}$	Fully mixed volume of a chest
τ_{ideal}	Time constant of the ideally mixed chest

Symbols

c	Consistency
$c_{xy}()$	Cross-covariance function
COV	Coefficient of variation, %
$H(\omega)$	Frequency response function
i	Imaginary unit, $\sqrt{-1}$
J_N	Squared cost function
$p_x()$	Probability density function
$P_x()$	Cumulative distribution function
s	Laplace variable
S_{xx}	Power spectrum
S_{xy}	Cross-spectrum
t	Time
V	Volume of a chest
W()	Windowing function
Q	Volumetric flow rate
μ	Mean
$\rho_{xy}()$	Cross-correlation function
σ	Standard deviation
τ	Time constant, delay
ω	Angular frequency, rad/s
γ^2_{xy}	Coherence

1. Introduction

This thesis work was carried out for the Tampere University of Technology at the Department of Automation Science and Engineering. The work was done in a co-operation with UPM-Kymmene. Water systems of modern mills are rather closed and fresh water consumption is minimized. This means that most of the circulation waters in the paper mill are cleaned and re-used e.g. as shower waters. Recovered material (fibres, ash and fines) is used as a raw material in papermaking. Cleaning is done usually by a disc filter. In papermaking process the disc filter is claimed to be one of the dominant disturbance sources, in particular regarding the ash consistency [1].

Stable thick stock mass flow is important for the papermaking process [2]. In particular, the dilution headboxes have been reported to be sensitive for incoming consistency variations [2]. These variations will result as quality variations of the paper. Stock is diluted in several stages and it flows through multiple mixing elements during the stock preparation and short circulation before entering the headbox. Dilution control attenuates slow consistency variations and the mixing elements fast ones. Large chests are used to eliminate the fast consistency variation with frequency higher than the cut-off frequency of the dilution controls, but they will cause high capital and energy costs. Recent studies [3] show that the disturbance attenuation of industrial chests is far from ideal. Ideas for redesigning the stock preparation system have been presented [1;4]. Thus it is important to establish the real mixing conditions of the chests and to study the disturbances coming from the disc filter.

1.1 Research problem

The objective of this thesis is to study total consistency and ash consistency variations coming from the disc filter. The magnitude of variations in the recovered stock total consistency and ash consistency are analyzed. Filler propagation through disc filter is studied. The ability of the industrial chests to attenuate disturbances is examined.

All the data studied in the analyses was collected from industrial-scale paper mill. Additional measurements were installed in the disc filter area to measure the recovered stock ash content and white water total and ash consistencies. The magnitude of variations in total and ash consistencies was studied using the collected data. Tracer tests were executed to study the mixing dynamics of recovered stock chest and blend chest. The distribution of filler between the flows in the disc filter area was studied based on the tracer tests.

The chest models were identified by minimizing the mean of squared deviation between the simulated and measured response. Simulations and data analyses were done with Matlab/Simulink software. Coefficient of variation is taken as the key measure for the magnitude of variations so that the comparison between different units or different process/control structures is possible. When estimating spectra and coherence the Welch method was applied.

1.2 Structure of the thesis

In Chapter 2 the papermaking process is introduced shortly and the disc filter operation and its placement in the papermaking are described. Chapter 3 discusses methods for controlling the fibre recovery process. Chest mixing dynamics is discussed and the chest models studied are presented in Chapter 4. In Chapter 5 the data collection and experiments at the case mill are described. Chapter 6 presents the data analysis methods applied in this thesis. The results obtained in this thesis are presented in Chapter 7. In Chapter 8 is the summary from the results of this thesis and there is also discussion about future research.

2. Fibre recovery in paper machine

Water systems at modern paper mills are rather closed, which means that fresh water consumption is minimized by reusing water as much as possible. As a result only 5-10 m^3 fresh water is consumed per produced paper ton in modern mills compared to older ones where the consumption can be as high as 30 m^3 per ton. This can be achieved only if the circulating water is cleaned so that it can also be used in positions at which the water with solid particles could block or break equipment. At the same time it is important to recover all the material in the water and reuse it as raw material in the process. Therefore fibres, filler and fines are recovered and water purified simultaneously at a paper mill, usually by the disc filter.

2.1 Papermaking process

Figure 2.1 shows an example of a super calendered (SC) paper production line stock preparation which is the type of process studied in this thesis. SC-paper is uncoated magazine paper which is mainly composed of mechanical pulp (60-80% of fibres in furnish). Chemical pulp (40-20% of fibres in furnish) reinforces the paper. In addition to the fibres the SC-paper has also mineral pigments as fillers (20-35% of solids content). High filler content provides good printability. [5]

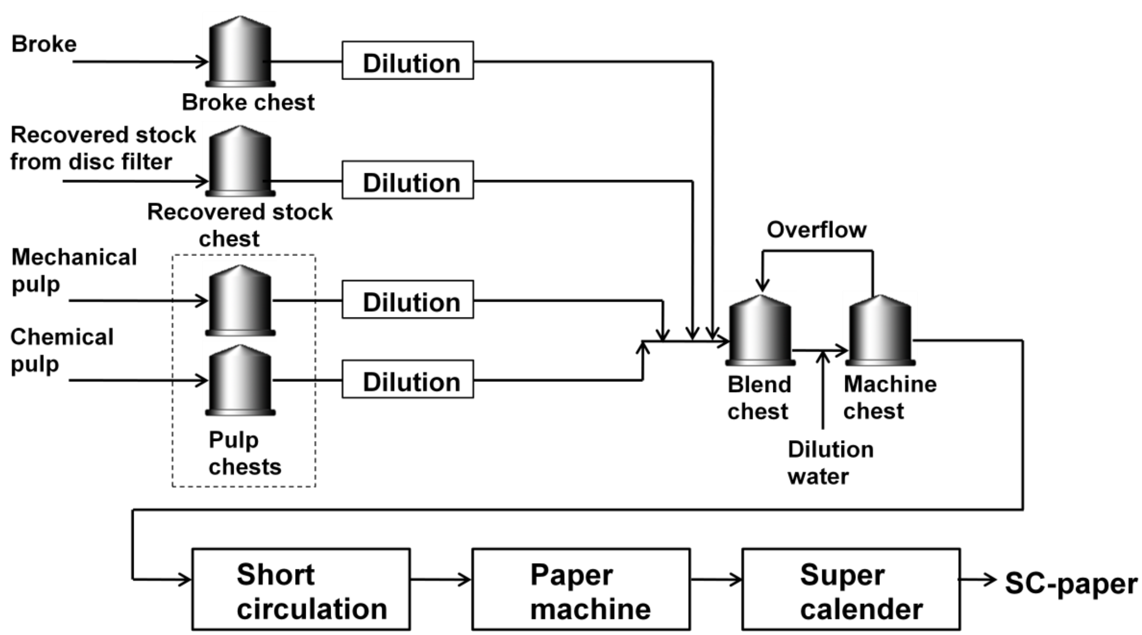

Figure 2.1. *Typical stock preparation and papermaking process on a SC-paper machine. [2, p.36]*

In stock preparation the stock is processed for the paper machine. To eliminate variations in quality, in particular in consistency, furnish components are diluted in several stages and mixed in large volumes [1]. Most commonly used mechanical pulps in SC-paper machine are thermomechanical pulp (TMP) produced by refining and pressurized groundwood pulp (PGW) produced by grinding. Chemical pulp is provided either as dried bales that are then pulped or, at integrated pulp and paper mills, as pumped never-dried slurry from the pulp mill.

After diluting and mixing the fibre flows each separately, the stock components are proportioned, blended, and further diluted to consistency appropriate for further processing [2]. The main stock components mixed in the blend chest are mechanical pulp, chemical pulp, broke and recovered raw material from the disc filter. Residence time in the blend chest should be long enough to ensure a reasonably homogenous mixture in the chest [2]. The blended pulp is pumped as a constant flow to the machine chest, which typically has an overflow back to the blend chest to ensure steady level in machine chest [1]. The stock is further diluted by a small amount, typically by 0.2% - 0.3% points, between the chests resulting in an approach flow to paper machine typically at 3% consistency[2].

The process area between the headbox of a paper machine and the stock preparation is called the short circulation. In the short circulation the stock from machine chest (thick stock) is diluted in the bottom of the wire pit with a white water from web forming to a consistency appropriate for the headbox operation (thin stock). Thin stock is fed from the wire pit to cleaning and deaeration which are another short circulation unit processes. The headbox distributes the flow from deaeration into a web-like structure. Majority of the water is removed at wire section and the removed water is collected to the wire pit.

Paper machine starts with a headbox and ends in a reeling section. In the headbox of a paper machine the consistency of the stock is 0.8-1.2% [5]. At present, dilution headboxes in modern mills provide an improved control of basis weight variations across the paper web, the basis weight profile. To realize the full potential of dilution headboxes wet end stability must be improved [1], which is the main motivation of this study.

Paper web is formed at wire section where most of the water (over 95%) is removed to the wire pit. Retention describes how big proportion of the solids entering the headbox stay on the wire. At SC paper machine the retention of the fillers, typically 20-40%, is far below to the retention of the fibres, which may be even over 90%. After the wire section the paper web is pressed and dried which removes the most of the remaining water and affects many of the characteristics of the paper. After drying at some paper machines there is a precalendering stage. In the reeling section the reel is formed and paper is ready for finishing operations [5].

Apart from the white water at wire pit being used for dilution, there is excess water, as the consistency of flow before dilution is about 3% and the web solids content at the end of wire section is about 20%. Excess water from wire pit is taken to the long circulation. This water is taken from the overflow of the wire pit as it is the cleanest fraction within the pit. Waters from the paper machine former, pressing and drying sections are also collected to the long circulation. Water in the long circulation is used, for example, in stock and broke dilution. However, the white water in the long circulation is not clean enough for many of the potential applications. Hence the solids are recovered and water cleaned in the long circulation. White water is opaque due to the solids, in particular fillers in it, hence the name “white water”. Solids are recovered from the white water with a disc filter so that the filtrated water fractions are collected according to their purity to be reused in papermaking process. Closing the water circulation at a mill reduces the need for fresh water. Figure 2.2 shows simplified structure of the long circulation. White water tower is a buffer to store a large amount of white water needed in particular during web breaks at the paper machine.

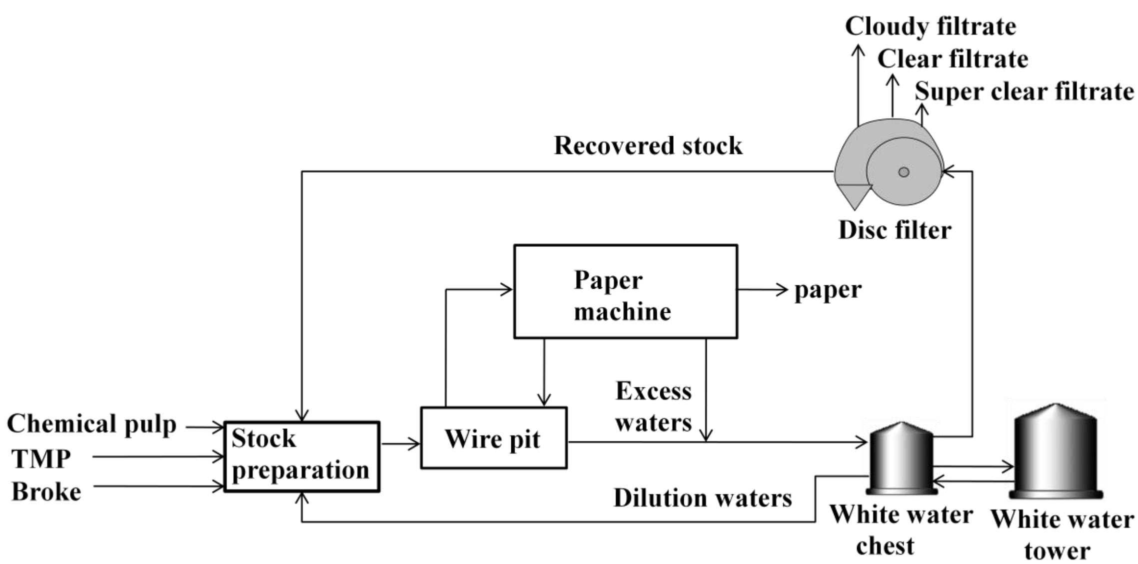

Figure 2.2. *Simplified structure of long circulation. [2, p.143]*

Supercalendering is a surface treatment unit process typically carried out off-line because it cannot normally handle the web at speeds of the paper machine. There can be several supercalenders in parallel to handle the amount of paper produced by the paper machine. Supercalenders usually have from 10 to 12 cylinders which treat the paper from both sides. Calendering increases smoothness and gloss of the paper. [6]

2.2 Fibre recovery with disc filter

The disc filter is a unit operation for large scale water filtration at paper mill. It recovers solids and filters water to be reused in papermaking. Disc filter consists of multiple, even over 30, discs rotating in a vat [2]. Discs are hollow, divided into sectors and covered with a filter cloth. Figure 2.3 shows a cross section of a Celleco Centerdisc CDI disc filter, which is the disc filter studied in this thesis. One of the discs in disc filter can be seen in the picture. The Centerdisc design differs from conventional disc filter design in that it lacks the central shaft so that the area of filtration and hence the capacity is higher than in more conventional designs [7]. Usually the discs are submerged about halfway in the slurry.

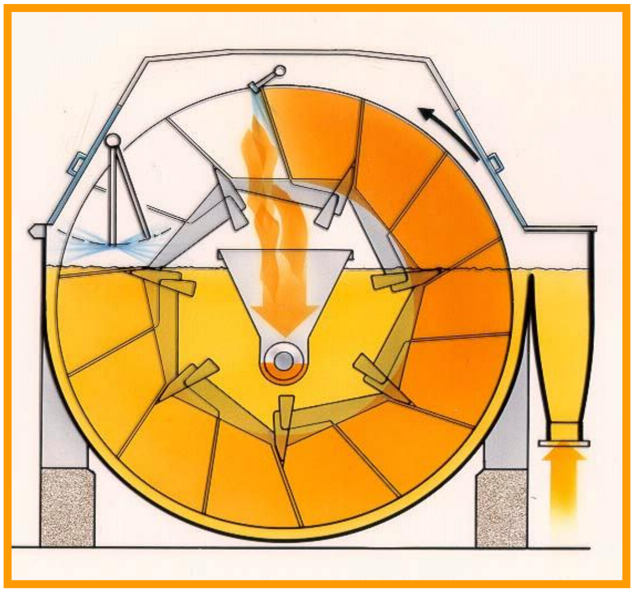

Figure 2.3. *Picture of a GL&V Celleco Centerdisc CDI. [8]*

2.2.1 Disc filter operation

Feed suspension enters the filter vat through a feed box, which spreads the suspension distributing it to cover the whole length of the shaft. Pulp mat starts to form on the surface of the filtering cloth with the aid of a vacuum inside the discs. Vacuum is created with drop legs of the filtrates. Difference in height between the center of the disc filter and the level in the filtrate tanks should be 7-8 meters to create required vacuum in the drop legs [2].

Filtrates are collected at one end of the disc filter via discharge channels. The channels go through the center of the disc filter and the disc segments are connected to them. The thicker the pulp mat is the fewer solids pass through it and hence the consistency of the filtrate decreases. Different filtrates are collected from different phases of the disc cycle.

The richer cloudy filtrate is collected in the beginning of the cycle when the filter cake is thin. The cleaner clear filtrate and the optional cleanest super-clear filtrate are collected after the filter cake is formed properly. The split ratio of the filtrates is either fixed or adjustable. By altering the access to the discharge channels adjusting is possible. [2]

In the end of the disc cycle the vacuum is removed and the filter cake is removed by knock off showers through the centre to a screw which transports the collected stock to the pipe leading to the recovered stock chest. The disc filter filtrate screw uses white water as dilution water. After the filter cake is removed the oscillating cleaning showers then clean the filtering cloths and the cycle begins again.

The capacity of a disc filter and the purity of the filtrates depend on feed consistency. Increasing the feed consistency decreases the capacity of a disc filter, but is essential to acquire clean filtrates. That is why pulp, usually referred as sweetener, is added to the disc filter feed to aid forming the filter mat. It is important to the disc filter operation that the stock properties of the sweetener are stable. Most important characteristic of the sweetener is its freeness which describes how easily water can be removed from the pulp. The best possible sweetener is long-fibre chemical softwood pulp. If there is not enough long-fibre chemical softwood pulp available the second best option is to use TMP.

Rotation speed of the discs is the second way to affect the capacity of disc filter and the purity of filtrates. Increasing the speed decreases the purity of the filtrates but increases the filtering capacity. Time given to the fibres to form a filter cake is determined by the rotational speed of the filter. Usually disc filters are driven with speeds ranging from 0.2 rpm to 1.5 rpm [2].

2.2.2 Placement of disc filter in papermaking process

Nissinen [1] has shown in his studies that in papermaking process the disc filter is one of the dominant disturbance sources, in particular regarding the ash consistency. This is due to the fact that disc filter recovers the solids, with high ash content in SC-paper, from the circulation water and feeds them back to the stock preparation. Figure 2.4 shows a typical disc filter process.

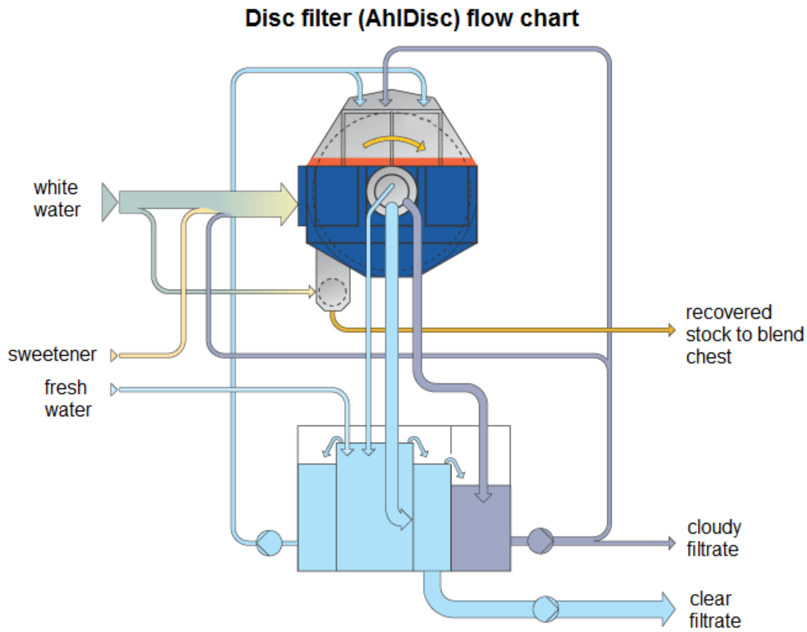

Figure 2.4. *Typical disc filter process at paper mill. [6]*

If capacity of one disc filter is inadequate two similar disc filters can operate in parallel. When running two disc filters in parallel, the filtration capacity is doubled. Both disc filters use the same recovered stock and filtrate chests. If purity of the filtrates is not adequate, two disc filters may be set up to operate in series.

The cloudy, clear and superclear filtrates are fed to dedicated chests each. Part of the cloudy filtrate is usually channeled back to the disc filter for further filtration. Clear filtrate can be used in pulp dilution and also as make-up water in stock preparation and in dry broke pulpers. Clear filtrate is also used in disc filter showers. Super clear filtrate is used in paper machine showers where the requirement of cleanliness is at its highest. Super clear filtrate chest has overflow to the clear filtrate chest which has also an overflow to the cloudy filtrate chest so that the cleaner filtrate can always be channeled to richer filtrate tank.

3. Methods of control for fibre recovery

In the fibre recovery area there are multiple controlled variables that will determine the performance of the disc filter. The most important of these are:

- white water flow to the disc filter,
- sweetener flow to the disc filter,
- disc filter screw dilution flow,
- disc filter rotational speed,
- disc filter level,
- recovered stock chest level,
- recovered stock flow to the blend chest, and
- recovered stock consistency.

In practice all the controllers at disc filter area are fixed parameter proportional-integral-derivative controllers (PID), most commonly with the derivative part not activated.

The disc filter level is controlled either by adjusting the rotational speed of the discs or by manipulating the flow of cloudy filtrate to the disc filter. Both methods affect purities of the filtrates, consistency of the recovered stock and the capacity of the disc filter. Disc filter level has a strong influence to the quality of the waters and the recovered stock. Thus it should be as stable as possible and to ensure this the incoming flows should not be fluctuating. The sweetener and white water flows to the disc filter are controlled in ratio to each other to ensure steady operation of disc filter. Ratio is adjusted so that a proper fibre mat forms to the filter cloth.

Figure 3.1 shows the conventional way to control the recovered stock chest level and recovered stock consistency. The valves are often controlled simply by altering their openings as shown in Figure 3.1. A more advanced option is to apply cascade controls in which level and consistency are controlled by manipulating the flows. In the inner level of the cascade the flow controllers drive the valve opening according to the set points provided by the outer level.

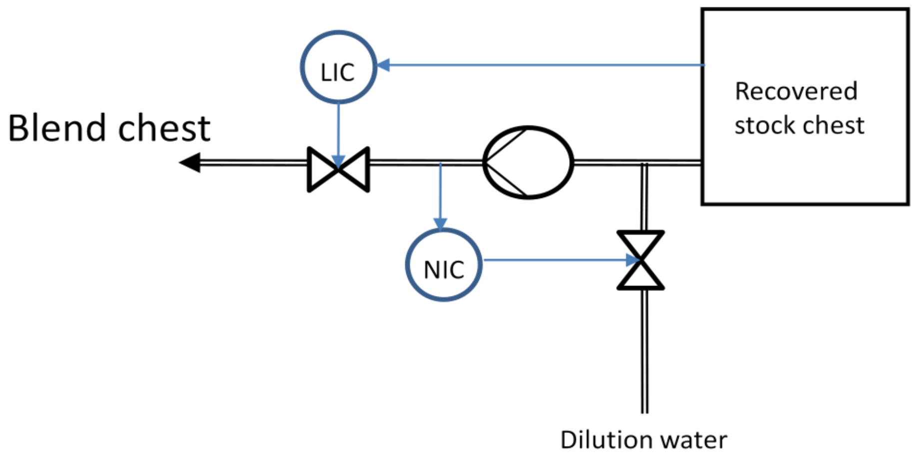

Figure 3.1. *The conventional way to control the level of recovered stock chest and consistency of the recovered stock.*

The conventional way to control consistency has several drawbacks. The process is non-linear because the process gain is inversely proportional to the flow rate. The control does not take into account the chances in the main flow rate. This means that the changes in the flow affect the dilution valve only after the changed consistency has been measured. The tuning of the controller should be carried out at the lowest flow rate to maintain stability at all flow rates. However, as a result the control performance can be far from optimal at higher rates (control is sluggish). A more sophisticated proportioning control strategy is presented in Figure 3.2. Here a varying main flow rate is compensated by a feedforward action based on the flow measurement to keep the dilution flow rate at constant proportion to main flow rate. [4]

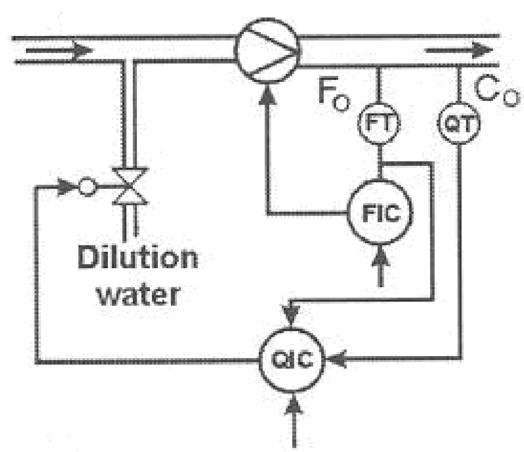

Figure 3.2. *Feedforward consistency control. [4]*

Controls in the disc filter area are expected to keep the consistency variations in the recovered stock at an acceptable level for the next stage, the blending chest. Slow consistency variations are reduced by multiple dilution stages with consistency controls before the paper machine. Fast consistency variations, especially above the cut-off frequencies of the control loops in the next stages, should be eliminated as well as possible. This is normally done with mixing in tanks.

3.1 Current practice at the case mill

This thesis studies the disc filter operation at a case mill. There are two disc filters working in parallel. The two disc filters have the same control structure and they work at identical operating points. Figure 3.3 shows the disc filter area and its control at the case mill. However, to keep the diagram simple only one of the disc filters is presented in the figure. The parallel disc filter has its own sweetener and white water inlets, and screw dilution water and recirculation from cloudy filtrate chest. The recovered stock and filtrates are collected from both of the disc filters into shared chests.

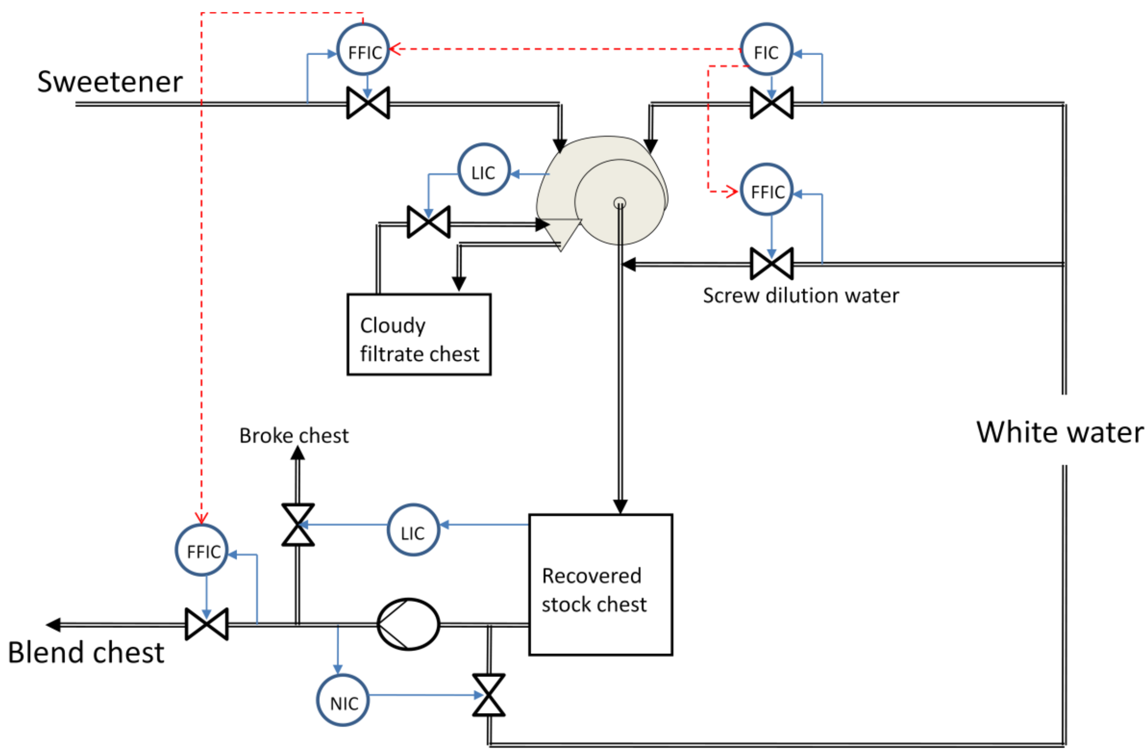

Figure 3.3. *Controls in the disc filter area at the case mill. Dashed red lines describe the relations of the controller setpoints. [9]*

White water flow to the filter is the main flow in this operation strategy: the operator at the mill selects the overall disc filter operating point by altering the white water flow to the filter. Sweetener flow to the disc filter and screw dilution water are controlled by PID-controllers having their setpoints in a given ratio to the white water flow. The ratio of the sweetener and white water is chosen such that a proper fibre mat builds at the filter cloth. Disc filter level is controlled by manipulating the cloudy filtrate flow back to the filter.

Recovered stock chest level is controlled by feeding part of the recovered stock flow to the broke chest. Level controller operates directly the valve controlling the flow. It is the goal in the operation that only a small amount of recovered stock is fed to the broke chest. However, the amount must be high enough to facilitate effective level control. The amount of the recovered stock flow to the broke chest is in under normal conditions 5-20% of the recovered stock flow to the blend chest [9].

Consistency of the recovered stock is controlled in the conventional way, as shown in Figure 3.1. Recovered stock flow to the blend chest is controlled to be in a ratio to the sweetener flow, and the operator gives the set point to this ratio. Changing the ratio affects directly the amount of recovered stock flow to the broke chest. Therefore how well the the operator can choose this ratio is crucial to the goal of having a small feed to broke chest .

This control method provides stable recovered stock flow to the blend chest. Consistency on the other hand will be disturbed by the recovered stock chest level control causing uneven discharge flow. Disturbances in the recovered stock chest level are transferred to the broke chest and eventually propagate from there to the blend chest.

3.2 Optifeed concept

The main goals of the Optifeed concept, developed by Metso, are to improve stock quality and efficiency of the stock preparation. In the Optifeed concept the fast consistency variation of the recovered stock is eliminated and transferred as slower one. This slow variation will be then handled by the process downstream. Disc filter operation with the Optifeed concept is presented in Figure 3.4.

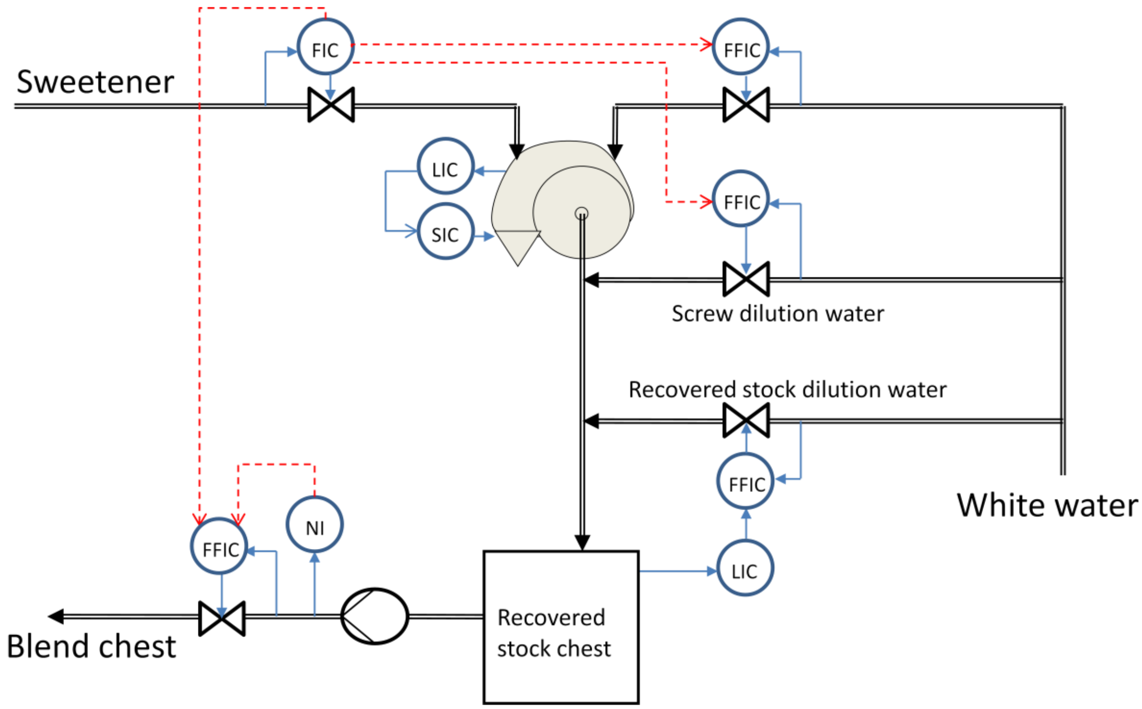

Figure 3.4. *Picture of the Optifeed concept. Dashed red lines describe the relations of the controller setpoints. [10]*

Sweetener flow to the disc filter is now the main flow and the white water and the screw dilution water flows are set in a user defined ratio to it. Sweetener to white water ratio is set such that a proper filter mat is formed on the filter cloth. Disc filter level is controlled by manipulating the disc filter rotational speed.

Recovered stock dilution water is supplied before the recovered stock chest. The chest level controller manipulates the flow rate of the dilution water. Recovered stock flow to the blend chest is controlled to be in ratio with the sweetener flow. The operator may vary the ratio. Recovered stock consistency is controlled with the following dead-band approach [10]:

- When the consistency increases, more dilution water is needed. When the consistency increases above a given deviation from the set point, the dead band, the ratio of the recovered stock flow to the sweetener flow is increased, thus increasing the recovered stock flow.
- As a result the level of the recovered stock chest decreases, which is compensated by increasing the flow of dilution water to the chest. Hence the chest consistency decreases.
- When the consistency decreases, the actions are the opposite.

The parameters of the dead-band control are the setpoint of consistency, the width of the dead-band, the change in the ratio, and control interval. For example, the parameters can be chosen as:

- setpoint of consistency: 3.2%,
- width of dead-band: ±0.02%-points,
- amount of change in the ratio: 3%-points, and
- change in ratio every 30 seconds.

Hence the controller checks every 30 seconds if the consistency of the recovered stock differs over 0.02% from the 3.2% and adjusts the ratio of the recovered stock and sweetener flow by 3%-point steps.

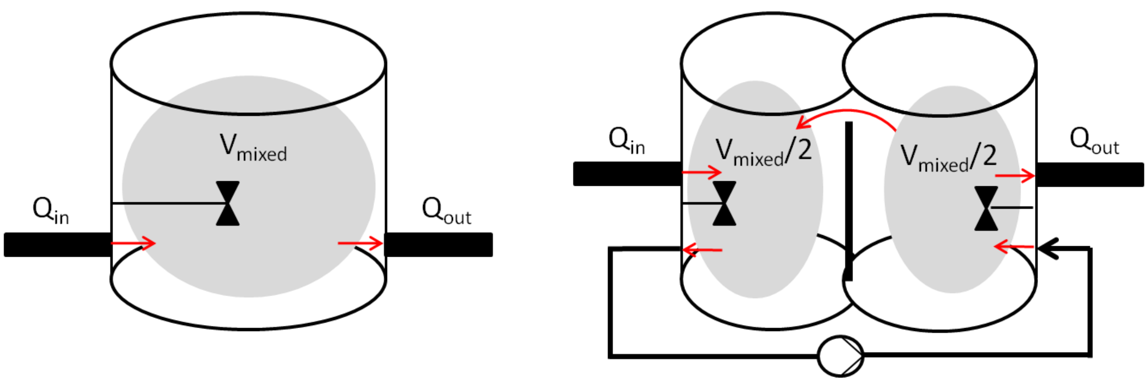

Figure 3.5. *Conventional chest with one agitated zone on the left and a dual chest with two agitated zones on the right.*

Recovered stock chest is a dual chest, see Figure 3.5 [10]. Dual chest is split into two parts and has two agitated zones. The recovered stock from disc filter is fed to the first chest where the agitation makes the first mixing. Stock is then pumped with constant volumetric flow to the second chest and agitated again before feeding to the blend chest. Second chest has an overflow to the first chest which has the level control. In this example the time constant of the mixing in the conventional chest is double compared to the time constants of the dual chest mixing zones. This assumption is valid if the following statements take place: flows through the chests (Q_{in},Q_{out}) are constant and equal and the volume of the two mixing zones in the dual chest are half the volume of the mixing zone of the conventional chest. This also means that there is no overflow in the dual chest in this example.

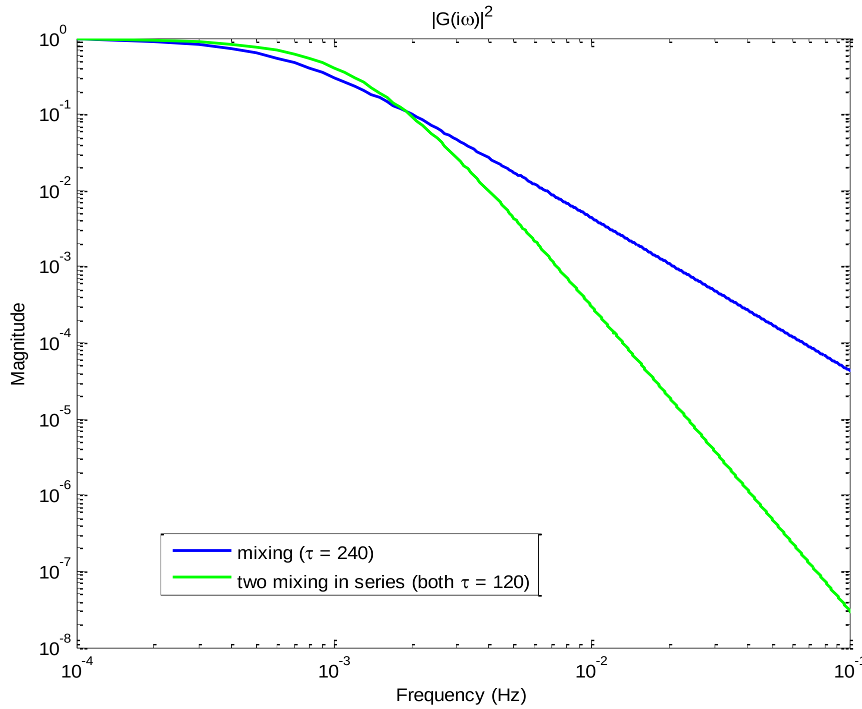

Figure 3.6. *Power transfer functions of conventional chest and dual chest.*

Figure 3.6 shows power transfer functions of the chests in the example. In the example the flows through the chests are constant and equal. The break frequency is the frequency where the absolute value of the power transfer function is 1/2. In the conventional chest the break frequency is approximately 0.006 Hz and in the dual chest 0.008 Hz. The power transfer functions show that even though the break frequency of the dual chest is inferior it should be more effective in eliminating variations at high frequencies. The basic principle of the concept in disc filter area is to keep the consistency variations at acceptable level and to reduce fast consistency variations. [10]

4. Agitated pulp stock chests

Agitated pulp stock chests have many functions in papermaking process [11]. They act as low-pass filters reducing high-frequency variation in concentration, freeness and other quality factors, and work as a buffer between process stages. Quality controllers reduce only the low-frequency variability. Therefore the chests and the controllers should be designed together to ensure sufficient disturbance attenuation at all frequencies, see Figure 4.1 [4]. Agitated chests can also mix several pulp stocks and process chemicals, acting as a blend chest [12]. The pulp suspension is stirred in the chest to prevent stock dewatering [12]. Sufficient agitation at the pulp exit location is important to prevent dewatering of stock before the stock enters the discharge pump [11].

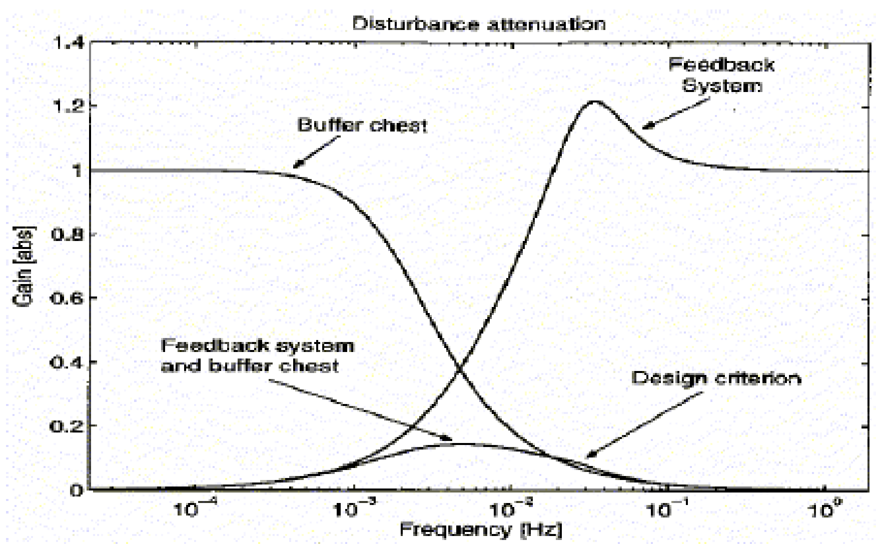

Figure 4.1. *Disturbance attenuation as a function of frequency. [4]*

In theory the disturbance attenuation of a chest can be improved by increasing the chest volume or by decreasing the flow through chest. However, a larger chest volume means increased investment costs which should be avoided. Flow through chest is the production rate and is thus usually set by other considerations than disturbance attenuation.

Recent studies [3;11;12;13;14] have shown that mixing in the chests is far from ideal. Current chest-control designs do not take this into account. Even complete surface motion does not guarantee that the chest is ideally mixed, in particular when fibre concentration exceeds 3% [11]. If ideal mixing is assumed – as is commonplace - the disturbance attenuation will be much poorer than anticipated. Therefore it is important to examine the actual response of the chests to achieve desired disturbance attenuation [11].

In this thesis chests are studied using four models as in [3]: ideal mixing, first order transfer function, non-ideal mixing and non-ideal mixing with mixing in sequence.

4.1 Ideal mixing and first order transfer function

Ideal mixing dynamics can be described with the equations of change of volume in the chest and change of substance in the chest as following [15]

$$\dot{V}(t) = Q_{in}(t) - Q_{out}(t) \tag{4.1}$$

$$\frac{d\big(V(t)c(t)\big)}{dt} = Q_{in}(t)c_{in}(t) - Q_{out}(t)c(t) \tag{4.2}$$

Where V is volume of the chest, Q_{in} is the volumetric flow in the chest inlet, Q_{out} is the volumetric flow in the chest outlet, c_{in} is the incoming flow consistency and c is the consistency in the chest and thus the consistency of the outgoing flow.

Using the equations 4.1 and 4.2 and assuming that flows in and out are equal so that the volume is constant we get the change of outgoing consistency [15]

$$\dot{c}(t) = \frac{Q_{in}(t)}{V}\big(c_{in}(t) - c(t)\big) \tag{4.3}$$

Then transforming the equation 4.3 into frequency domain, and assuming constant volume as a result of constant and equal incoming and output flows, we get first order dynamics with time constant V/Q_{in}

$$H(\omega) = \frac{1}{\frac{V}{Q_{in}} i\omega + 1} \tag{4.4}$$

General first order transfer function may be used to represent mixing in the chest. Although the form of it is alike the ideal mixing the time constant τ is evaluated from the measured response, not from the flow and volume as in ideal mixing. First order transfer function can be interpreted as one representing a chest consisting of a dead zone and an ideally mixed zone [3]. Block diagram of the first order transfer function is shown in Figure 4.2 and the model is ideal mixer if the time constant τ_2 is V/Q_{in}.

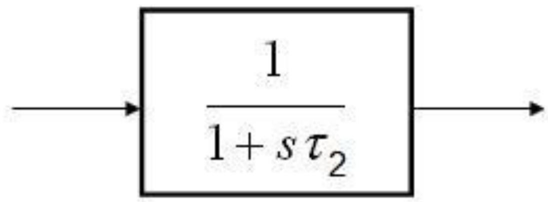

Figure 4.2. *Block diagram of first order transfer function.*

If the flow rate through the chest at constant level is known, the fully mixed volume of the chest can be approximated as

$$V_{fully\ mixed} = \tau_2 Q \tag{4.5}$$

Although the first order transfer function does not describe the system performance and phenomena well enough, the estimate of ideally mixed volume is quite informative. [3]

4.2 Non-ideal mixing models

Recent studies [3;11] show that non-ideal phenomena such as channeling, recirculation and stagnant regions exist in industrial stock chests. This is partly due to the complex rheology of pulp fibre suspension [14]. As the concentration of the suspension increases the network shear strength increases, which makes agitation of the suspension increasingly difficult. Figure 4.3 shows a simplified block diagram of a non-ideal chest model consisting of a mixing part and a channeling route. Proportion of channeling f describes how large amount of incoming flow goes to output straight without almost any mixing, described by a time constant τ_1. Rest of the flow goes through mixing zone with a time constant τ_2 with a possible recirculation rate R. Time delays T_1 and T_2 express the dead times inside the chest.

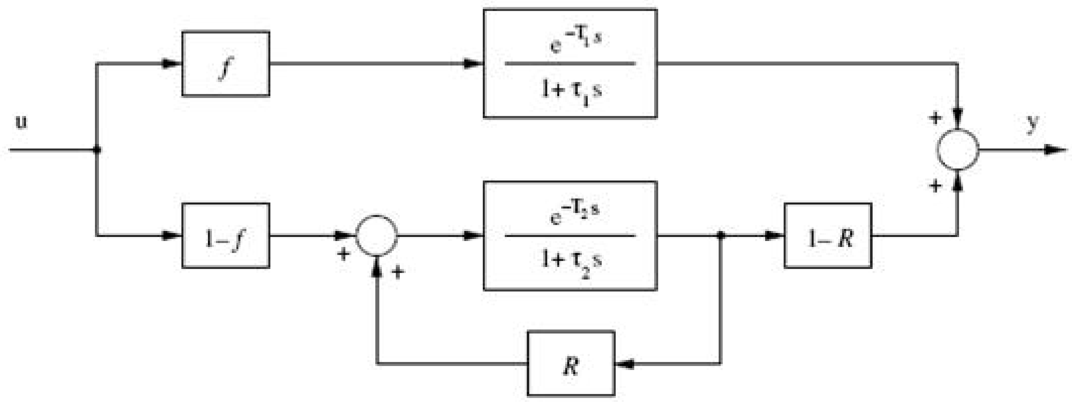

Figure 4.3. *Simplified block diagram of non-ideal chest model. [14]*

Figure 4.4 shows the block diagram for non-ideal mixing with mixing in sequence. Time constant τ_3 expresses the time constant of the additional mixing.

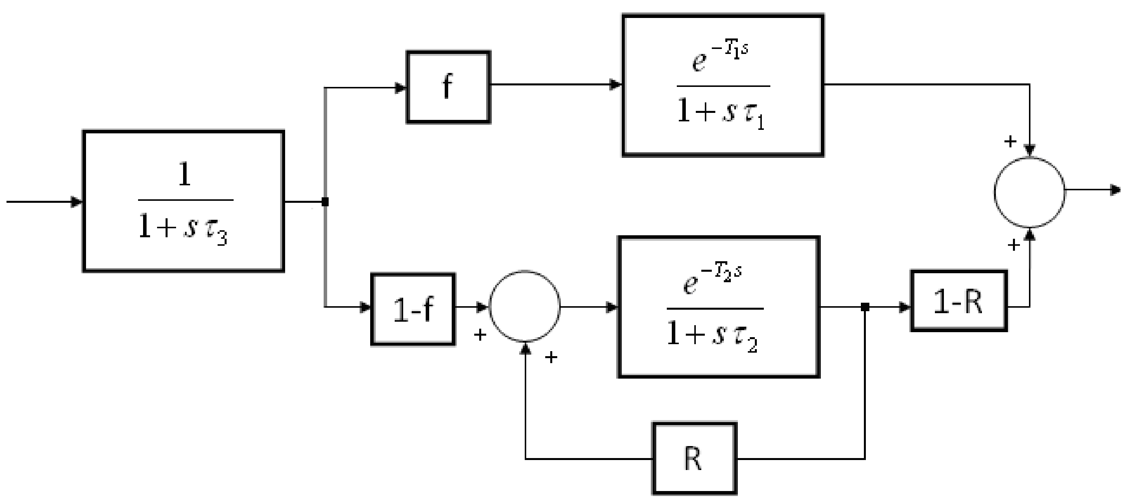

Figure 4.4. *Block diagram of non-ideal mixing with mixing in sequence. [3]*

Studies [3] show that the recirculation parameter R is close to zero in industrially relevant chest. Estimates for parameters f, T_1 and τ_1 are rather insensitive to whether the recirculation path is included or not. Analyses made during this thesis support this observation. Hence, for simplicity, the recirculation is ignored by setting R = 0. Doing this and using the pulp flow rate through the chest Q and the analyzed variables τ_2 and f we get the fully mixed volume of the chest for the non-ideal chest model [12]

$$V_{fully\ mixed} = \tau_2(1-f)Q \tag{4.6}$$

The fully mixed volume of the chest for the non-ideal mixing with mixing in sequence is

$$V_{fully\ mixed} = (\tau_2(1 - f) + \tau_3)Q \tag{4.7}$$

The non-ideal behavior of the chests and especially the critical high frequency disturbance attenuation can be studied with the non-ideal mixing models. Ideal mixing and first order transfer function models assume that all incoming stock goes through the mixing zone and therefore they cannot describe the channeling of the fast variations through the chests. The non-ideal mixing models take into account that part of the incoming stock channels through the chest without almost any mixing.

5. Data collection and experiments

In this chapter the data collection, additional measurements, and experiments made at the case mill are described.

5.1 Data collection

Data from the disc filter area at the case mill was collected with a 0.2Hz sampling frequency. Variables collected were all measurements, setpoints and control signals of controllers available through the process control system, see Appendix 1. For this thesis the most important variables are listed in Table 5.1. Recovered stock consistency was measured with a BTG shear force device. This device is insensitive to filler consistency and thus measures only fibre consistency variations. The device can be calibrated for total solids consistency, but then the assumption is that the ratio of fillers to fibers is constant. The calibration for the device was executed this way and the ratio of fillers to fibres is the one which was during the calibration.

Variable	Measurement	Setpoint	Control signal
Sweetener flow to disc filter 1	l/s	l/s	%
Sweetener flow to disc filter 2	l/s	l/s	%
White water flow to disc filter 1	l/s	l/s	%
White water flow to disc filter 2	l/s	l/s	%
Cloudy filtrate flow to disc filter 1	l/s	-	-
Cloudy filtrate flow to disc filter 2	l/s	-	-
Recovered stock chest level	%	%	%
Recovered stock total consistency	%	%	%
Recovered stock flow to blend chest	l/s	l/s	%
Total consistency of white water to the disc filters	%	-	-
Ash consistency of white water to the disc filters	%	-	-
Recovered stock ash content	%	-	-

Table 5.1. *Variables collected at the case mill. Units for the measurement, setpoint and control signal presented.*

Two KajaaniRM3^{TM} sensors were installed at the case mill, see Figure 5.1. One of the sensors measured the total and ash consistencies of the white water. The other sensor was installed to measure the recovered stock. Recovered stock had to be diluted before the measurement because RM3s are able to measure consistencies only up to 2%, and the recovered stock consistency exceeds this limit [16]. Dilution does not affect the ratio of total consistency to ash consistency so the ash content of recovered stock can be calculated from RM3 results.

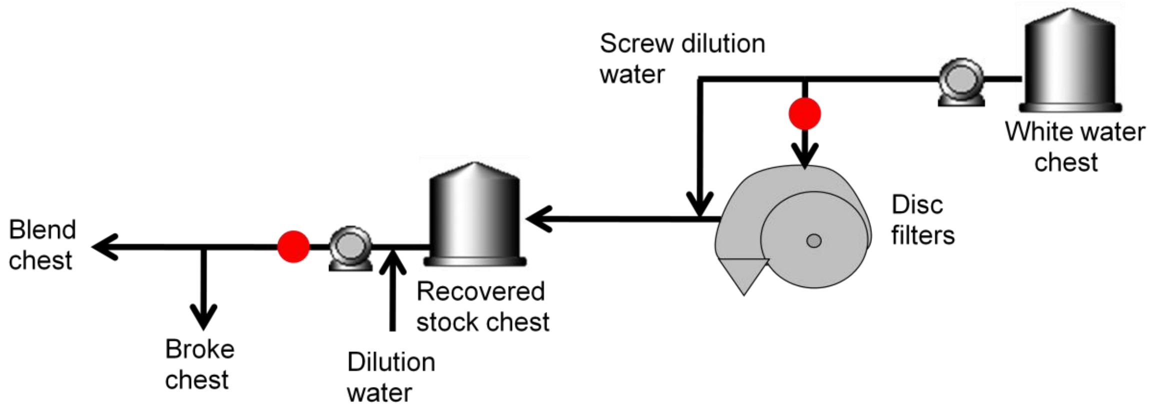

Figure 5.1. *RM3 placement at the case mill. Red balloons show the locations of the sensors.*

Total consistency c_{tot} of the stock is defined as

$$c_{tot} = \frac{dry\ weight\ of\ the\ sample}{total\ weight\ of\ the\ sample} * 100\% \tag{5.1}$$

If the results are expressed in g/l as RM3 does, the total consistency is defined as

$$c_{tot} = \frac{dry\ weight\ of\ the\ sample}{volume\ of\ the\ sample} \tag{5.2}$$

Ash consistency c_{ash} is defined as

$$c_{ash} = \frac{weight\ of\ ash\ in\ the\ sample}{total\ weight\ of\ the\ sample} * 100\% \tag{5.3}$$

or as the RM3 measures

$$c_{ash} = \frac{weight\ of\ ash\ in\ the\ sample}{volume\ of\ the\ sample} \tag{5.4}$$

Ash content of paper is defined

$$Ash\ content = \frac{c_{ash}}{c_{tot}} * 100\% = \frac{weight\ of\ ash\ in\ the\ sample}{dry\ weight\ of\ the\ sample} * 100\% \quad (5.5)$$

Magnitude of total consistency and ash consistency variations in white water can be evaluated using the RM3 measurements. Magnitude of the total consistency variation in the recovered stock has to be evaluated using the BTG shear force device measurement and thus the result is only the fibre consistency variation multiplied by a constant which is defined during calibration of the device. This constant is not known but it can be estimated from the RM3 recovered stock ash content measurement with the presumption that the process conditions were the same during the calibration as they were during normal process operation measured with the RM3. The variation in the RM3 recovered stock ash content measurement is also used to estimate the magnitude of recovered stock ash consistency variation.

5.2 Tracer experiments

Tracer tests were executed at the case mill in order to determine how filler (kaolin) is distributed to the outflows at the disc filter and to study mixing dynamics of recovered stock chest and blend chest. The tests were implemented by the company Indmeas. Tracer substance in filler distribution measurements was irradiated dry kaolin powder which contained ^{24}Na-radioisotope. In the chest mixing dynamic tests the tracer substance was water-soluble radioactive K^{82}Br. Before the measurement data was analyzed the effect of the average background radiation was subtracted from the results. The decrease in radioactivity in K^{82}Br, caused by the radioactive decay, was taken into account. Because the radioactive half life of the ^{24}Na-radioisotope is quite long, approximately 15h, the decay correction was not necessary in the filler distribution measurements. [17]

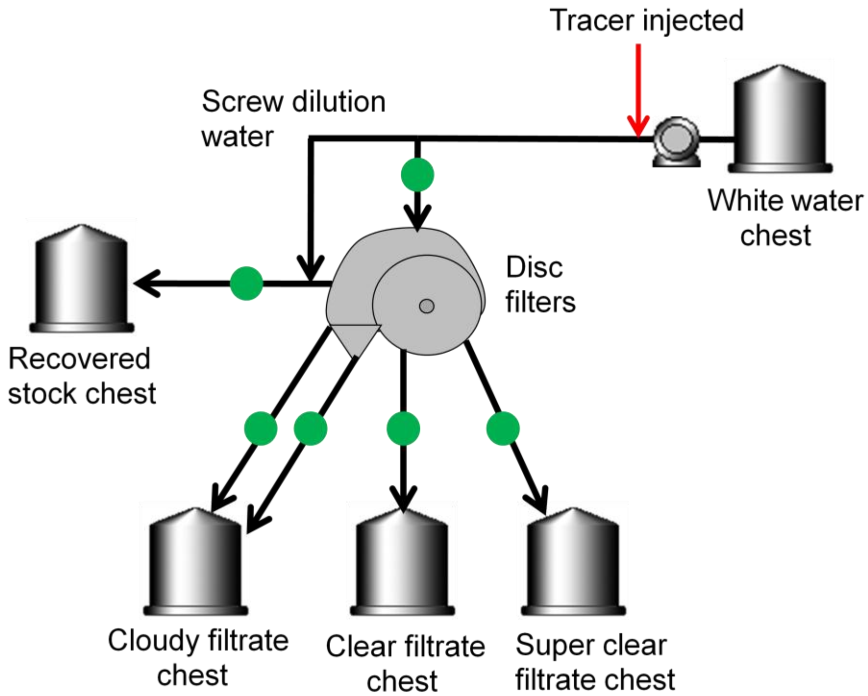

Figure 5.2. *Test arrangements for the kaolin distribution in disc filter. Green balloons show the locations of the radiation detectors for one disc filter.*

Figure 5.2 shows the test arrangements for measuring the filler distribution at disc filter. Tracer substance was injected as a short impulse into the white water line leading to both disc filters. Radioactivity was measured simultaneously with radiation detectors in the pipelines after the disc filters. The detectors were placed on top of the pipes at identical locations at both disc filters. There is an additional line to the cloudy filtrate, called after-filtrate, at which radioactivity was also measured and it was added to the cloudy filtrate measurements in the analyses. Because the installation geometries of the detectors and flows in the pipelines differ the detectors had to be calibrated to provide results that can be compared. Calibration was carried out by injecting the same amount of $K^{82}Br$ solution to the lines, which then provided weighting coefficients for the responses. The dilution water of the recovered stock screw is also white water. Hence part of the tracer injected went straight to the disc filter screw and from there to the recovered stock chest. Recovered stock detectors measured this tracer and it was discarded in the analyses.

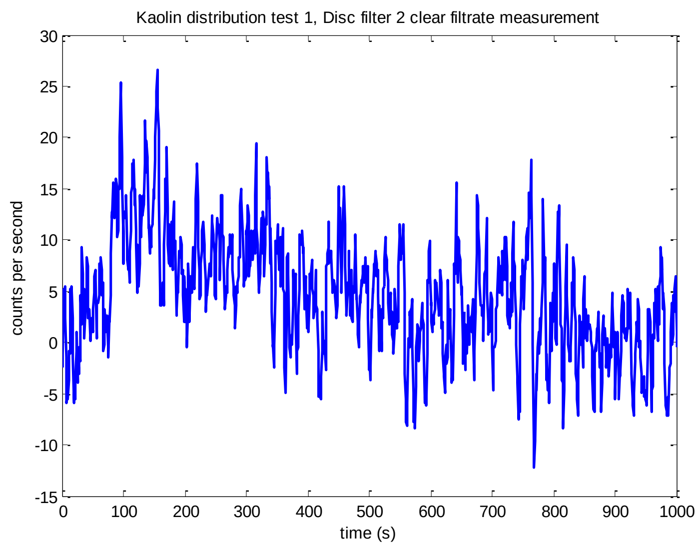

Figure 5.3. *Tracer response curve from disc filter 2 clear filtrate line. Background radiation and weighting coefficient taken into account.*

A typical tracer response curve is given as Figure 5.3. The time integral of the response curves measured with radiation detectors gives the total amount of tracer substance that has gone through the measurement point.

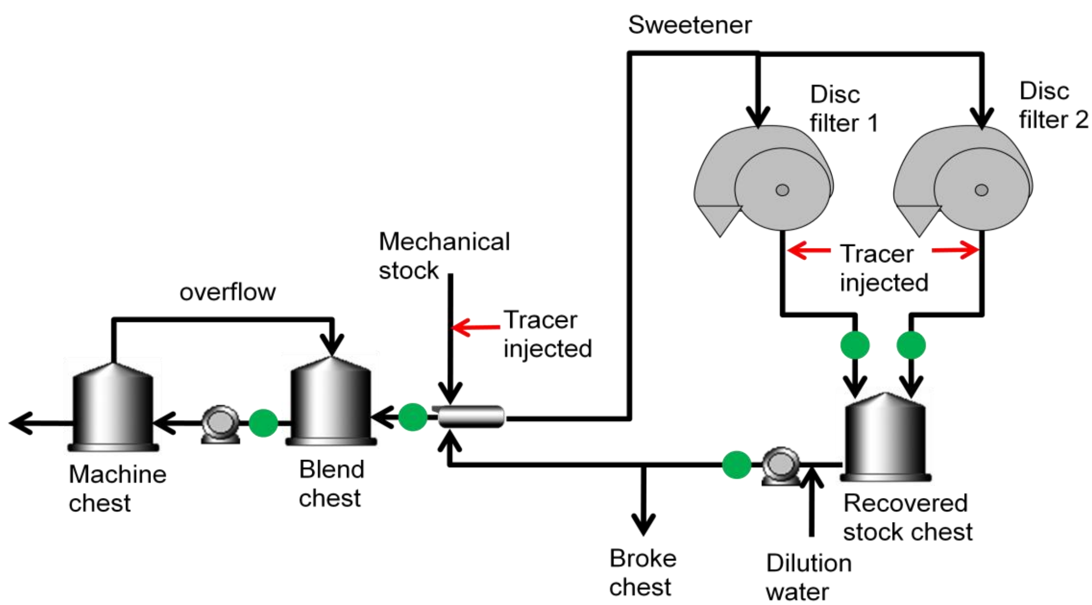

Figure 5.4. *Tracer tests for the recovered stock- and blend chest. Green balloons show the locations of the radiation detectors.*

Figure 5.4 shows the experimental arrangements for analyzing the mixing dynamics of the chests. In the recovered stock chest measurements the tracer substance was injected alternatively to both of the disc filter outlets. Tracer was injected through the disc filter screw maintenance shaft so that the tracer travelled through the screw before entering the recovered stock chest. That is why the measured input to the chest was mixed and not an impulse, see Figure 5.5. This was not a problem for the analysis method applied for identifying dynamic system models. The amount of tracer was measured with radiation detectors in the inlet and at the output of the chest. This method was used also in the blend chest measurements where the tracer substance was injected to the pulp flow before the chest and the measured inlet was an impulse, see Figure 5.6.

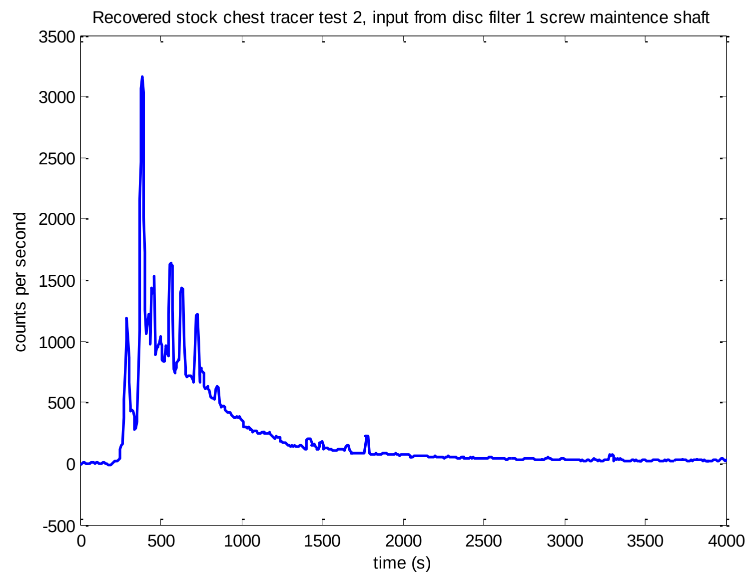

Figure 5.5. *Example of measured input to the recovered stock chest.*

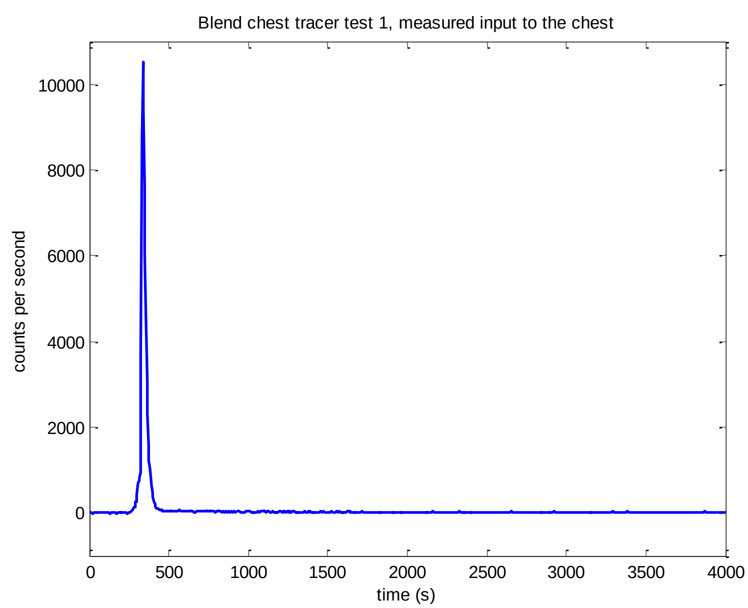

Figure 5.6. *Example of measured input to the blend chest.*

The curves measured at the output of the chests are called exit age-distributions E(t) or residence time distributions, see Figure 5.7 for an example. Curves are scaled so that their time integral is 1.

$$\int_0^\infty E(t) = 1 \tag{5.6}$$

The input to the chest is also scaled the same way. Thus the residence time distribution is identical to the weight function of the system, see [18].

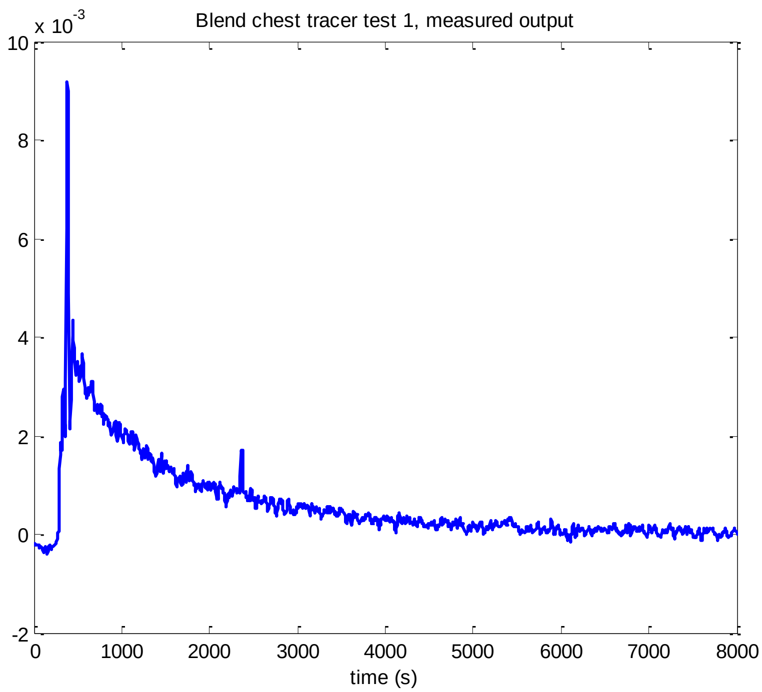

Figure 5.7. *Example of measured and scaled output of the blend chest.*

In the filler distribution tests tracer was injected 5 times, in the blend chest mixing dynamics tests 5 times, and in the recovered stock mixing dynamics tests 4 times to both disc filter screw maintenance shafts simultaneously. There was a waiting time between each injection to ensure that the tracer from previous test has faded. Results are presented as an average of all injections.

6. Data analysis methods

In this chapter the data analysis methods applied in this thesis are described. The analyzed signals in this thesis are assumed stationary. The condition for a a system to be stationary in wide sense is that the mean and the variance are time-invariant [19]. The wide sense of stationary is usually sufficient during analyzes.

6.1 Parameter estimation for the chest models

Parameters for the chest models presented in Chapter 4 were estimated with tracer test data. Parameters were estimated by minimizing a cost function J_N which is the mean squared deviation between the measured output y^m and the simulated response of the model based on the measured input u^m:

$$J_N = \frac{1}{N}\sum_{t=1}^{N}(y^m(t) - \hat{G}u^m(t))^2 \tag{6.1}$$

where Ĝ is the simulated chest model (see Table 6.1) , N is number of samples in measured input and output data, y^m is the measured output of the chest, u^m is the measured input of the chest.

Ĝ	First order transfer function	Non-ideal mixing	Non-ideal mixing with mixing in sequence
Time constant of channeled flow, τ_1	-	+	+
Dead time of channeled flow, T_1	-	+	+
Time constant of ideally mixed zone, τ_2	+	+	+
Dead time of ideally mixed zone, T_2	+	+	+
Time constant of additional mixing in sequence, τ_3	-	-	+
Amount of channeled flow in ratio with the total flow,f	-	+	+
Amount of recirculation in the chest, R	-	+	+

Table 6.1*. Parameters for the simulated chest models. Parameters included in the model are marked with + and parameters excluded are marked with -.*

Recirculation in the chest was ignored by setting R = 0. Simulations for the parameter estimation were made with Matlab/Simulink software.

6.2 Normal distribution

The cumulative distribution function $P_X(x)$ defines the probability for a random variable X to be smaller or equal as x [19]

$$P_X(x) = P\{X \leq x\} \tag{6.2}$$

The derivative of the cumulative distribution function is the probability density function p_X [19]

$$p_X(x) = \frac{dP_X(x)}{dx} \tag{6.3}$$

If the probability density function of a random variable is the shape of a Gaussian curve the variable is said to be normally distributed [19]

$$p_x(x) = \frac{1}{\sqrt{2\pi\sigma_x^2}} e^{-(x-\mu_x)^2/2\sigma_x^2} \tag{6.4}$$

Normally distributed variable has a mean μ_X and a standard deviation σ_X. From The mean of a random variable X is estimated based on N samples of data as [19]

$$\hat{\mu}_x = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{6.5}$$

The unbiased estimate of standard deviation is [19]

$$\hat{\sigma}_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \hat{\mu}_x)^2} \tag{6.6}$$

In the analyses the measurements have been fitted to the normal distribution using the estimates of the mean and standard deviation, see Figure 6.1. The histogram and the fitted normal distribution curve are both scaled so that their integral over values of random variables is 1.

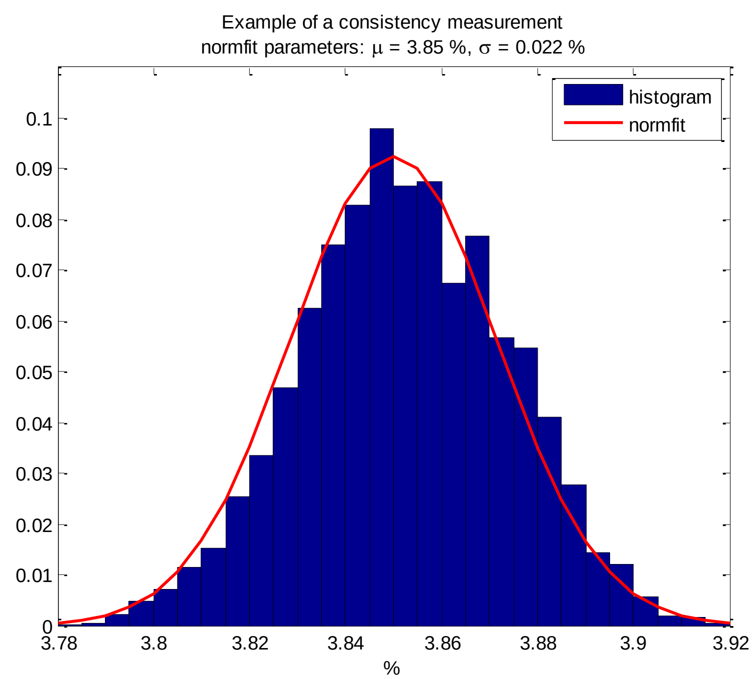

Figure 6.1. *Example of a consistency measurement at the case mill. Normfit is the normal distribution curve with the estimated mean and standard deviation.*

How close the data represents a normally distributed variable is examined only by visual comparison rather than with quantitative methods of validating the normality assumption.

6.3 Coefficient of variation

In this thesis the magnitude of variation in measured variables is expressed by using the coefficient of variation (COV). COV is defined as a ratio of standard deviation σ and mean μ, and it is expressed in this thesis as percentages

$$COV = \frac{\sigma}{\mu} * 100\% \tag{6.7}$$

The coefficient of variation gives a way to compare data sets with different means or different units, for example when comparing variation in flow and in consistency. It can be understood also as scaling of data so that it is made anonymous.

6.4 Cross-correlation function

Two stationary random signals x and y can be analyzed by their joint statistical properties, such as: [19]

$$r_{xy}(\tau) = E[x(t)y(t+\tau)] \tag{6.8}$$

According to the stationarity assumption, such statistical properties depend only on the time difference variable τ, not on the absolute time t. Cross-covariance function is defined as [19]

$$c_{xy}(\tau) = E\big[(x(t) - \mu_x)\big(y(t+\tau) - \mu_y\big)\big] \tag{6.9}$$

where E[] is the expected value operator and μ_x and μ_y are the mean values of the signals.

Cross-spectrum is defined as the Fourier transform of the cross-covariance function:

$$S_{xy}(f) = \int_{-\infty}^{\infty} c_{xy}(\tau) e^{-j2\pi f\tau}\, d\tau \tag{6.10}$$

Normalized cross-covariance function known also as cross-correlation function is defined as [19]

$$\rho_{xy}(\tau) = \frac{c_{xy}(\tau)}{\sigma_x \sigma_y} \tag{6.11}$$

where $-1 \leq \rho_{xy}(\tau) \leq 1$

The cross-correlation function describes the strength of linear statistical dependence of signals in a delay τ. If there is no dependence the function gets a value 0. Absolute value of the function is 1 if the signals are determistically linearly correlated at some delay.

6.5 Power spectrum estimation

Power spectrum describes how the variance of the signal is distributed over frequencies. Comparison of power spectrum estimation methods can be found in [3]. In this thesis the power spectra were estimated with the Welch method [19]. It is a direct spectrum estimation method which means that it operates with Fourier transform on the raw data.

Power spectrum can be estimated as a periodogram which means making a direct Fourier transform for the signal as [19]

$$\hat{S}_{xx}[f_k] = \frac{1}{N f_s} \left| \sum_{n=0}^{N-1} x[n] e^{-j2\pi n f_k / f_s} \right|^2 \tag{6.12}$$

Where k = 0,1,2,…,N-1, $f_k = f_s k/N$, f_s is sampling frequency, N is the amount of samples.

The resolution at the frequency axis is then

$$\Delta f_k = \frac{f_s}{N} \tag{6.13}$$

Frequency resolution improves when the amount of samples N is increased.

Reliability of the periodogram estimate of spectrum can be improved by averaging over a number of individual periodograms. The signal with a length N is divided into segments of lengths M. The number of segments is thus K = N/M. Periodograms are estimated for each segment $x_m[n]$ separately and the new estimate is an average of these [19]

$$\hat{S}_{xx}[f_k] = \frac{1}{K} \sum_{m=0}^{K-1} \hat{S}_{xx(m)}[f_k] \tag{6.14}$$

Where

$$\hat{S}_{xx(m)}[f_k] = \frac{1}{M f_s} \left| \sum_{n=0}^{M-1} x_m[n] e^{-j2\pi n f_k / f_s} \right|^2 \tag{6.15}$$

k = 0,1,2,…,M-1.

Averaging makes the estimate smoother but decreases the frequency resolution because the segments are shorter than the original signal.

When a discrete Fourier transform is done to a finite length measurement it is continued periodically to an infinite one. This causes discontinuities at the periodic extension continuations. These discontinuities cause a phenomenon called spectral leakage. This means that frequencies outside the basis set are not periodic in the observation window and they leak non-zero projections on the entire basis set [20]. Windowing functions are used to reduce the spectral leakage by weighting the signal to zero or near zero at the ends of the finite length sample. Different windowing functions were compared in [20] and the author recommends the Blackman-Harris window. The minimum 4-term Blackman-Harris window function is

$$W(n) = a_0 - a_1 \cos\left(\frac{2\pi}{N} n\right) + a_2 \cos\left(\frac{2\pi}{N} 2n\right) + a_3 \cos\left(\frac{2\pi}{N} 3n\right) \tag{6.16}$$

a_0=0.35875, a_1=0.48829, a_2=0.14128, a_3=0.01168 and n = 0,1,2,…,N-1.

Welch spectrum estimate is a modified averaged periodogram where the segments can overlap. The signal with a length N is divided into K segments with a length of M. The starting points of these segments are D units apart. The first segment is then [21]

$$x_1[n] = x[n] \tag{6.17}$$

n = 0,1,2,…,M-1.

The second segment is [21]

$$x_2[n] = x[n + D] \tag{6.18}$$

n = 0,1,2,…,M-1.

The final segment is [21]

$$x_K[n] = x[n + (K - 1)D] \tag{6.19}$$

n = 0,1,2,…,M-1.

For each of these segments the periodogram is calculated as [21]

$$\hat{S}_{xx(k)}[f_k] = \frac{1}{Mf_s}\left|\sum_{n=0}^{M-1} W(n)x_k[n]e^{-j2\pi n f_k/f_s}\right|^2 \quad (6.20)$$

Where k = 1,2,…,K and W(n) is the selected windowing function.

Estimate is calculated at frequencies [21]

$$f_k = f_s\frac{n}{M} \quad (6.21)$$

n = 0,1,…,M/2.

The multiplicative factor U is used to compensate the loss of signal energy in windowing [21]

$$U = \frac{1}{M}\sum_{n=0}^{M-1} W(n)^2 \quad (6.22)$$

The Welch spectrum estimate is the average of the calculated periodograms [21]

$$S_{welch}[f_n] = \frac{1}{K}\sum_{k=1}^{K}\frac{M}{U}\hat{S}_{xx(k)}[f_k] \quad (6.23)$$

Typically overlap is chosen to be 50%. When using longer segments the frequency resolution is better. Increasing the number of segments reduces the variance of the spectrum estimate.

6.6 Coherence

Coherence describes the linear correlation between signals as a function of frequency. Coherence is defined using the power spectra and cross-spectrum as [19]

$$\gamma_{xy}^2(f) = \frac{\left|S_{xy}(f)\right|^2}{S_{xx}(f)S_{yy}(f)} \quad (6.24)$$

And from the inequality [19]

$$\left|S_{xy}(f)\right|^2 \leq S_{xx}(f)S_{yy}(f) \tag{6.25}$$

it follows that $0 \leq \gamma^2_{xy}(f) \leq 1$.

Coherence is symmetric about the zero frequency so only the positive frequencies are needed to inspect. Coherence is near 1 if the spectra of signals are similar at the corresponding frequency. For uncorrelated signals the coherence is zero. Weak coherence can mean that the measurement noise is much larger than the real signal in one or both of the signals or that the system between the signals is non-linear.

Transfer function can be estimated for a system between measured signals. One way to do this is by using the power spectrum of the input signal S_{xx} and the cross-spectrum between the input and output signals S_{xy} as [19]

$$H(f) = \frac{S_{xy}(f)}{S_{xx}(f)} \tag{6.26}$$

The transfer function estimate is valid only in frequencies where the coherence is near 1. Thus coherence can be used to determine if transfer function estimation is needed.

7. Results

In this chapter the main results of this thesis are presented. Results for the tracer tests described in Chapter 5 and the observations made using the collected data are also presented here.

7.1 Flows and consistencies at the case mill

In this section the flows and consistencies in the disc filter and stock preparation area at the case mill are studied. Filler distribution in disc filter was studied with tracer tests described in Section 5.2. Ideal time constants of the recovered stock chest and blend chest are also estimated using the flow measurements from the time during the filler distribution tracer tests.

7.1.1 Filler distribution in disc filter

Filler distribution in disc filter was studied with tracer tests executed during normal operation at mill. Measurements were done simultaneously to both disc filters. The distribution of filler between the flows from disc filter during normal process operation is presented in Table 7.1. Approximately 52% of the filler going to disc filters propagates to the recovered stock and the rest goes to the filtrate waters.

	To recovered stock chest (%)	To cloudy filtrate (%)	To clear filtrate (%)	To super clear filtrate (%)
Disc filter 1	49	18	16	17
Disc filter 2	55	15	17	13

Table 7.1. *Kaolin distribution in disc filter.*

The amount of tracer in white water flow to the disc filter screw was calculated from the measurements. Using this we get the ratio of the white water flow to the disc filter screw compared to the total white water flow to the disc filter (which means both the white water flow to the disc filter and flow to the disc filter screw added together). This ratio was 15 % in disc filter 1 and 17 % in disc filter 2 calculated using the tracer test results. Using the flow measurements during the time of the tests this same ratio was 17% in both disc filters. The calculated ratios in both cases are close to each other so that strengthens the validity of the tests.

7.1.2 Flows and consistencies in the disc filter area

Figure 7.1 shows the flows and consistencies in the disc filter area. Flows presented in the chart are to and from both disc filters. The disc filter shower waters were excluded from the analyses because they were not measured and their influence would be minor. The colors in the picture represent where the values are taken from: blue values are measured, green values can be calculated using the known values and red values are looked from PI-chart of the case mill. Real values are not shown in the figure because they are confidential.

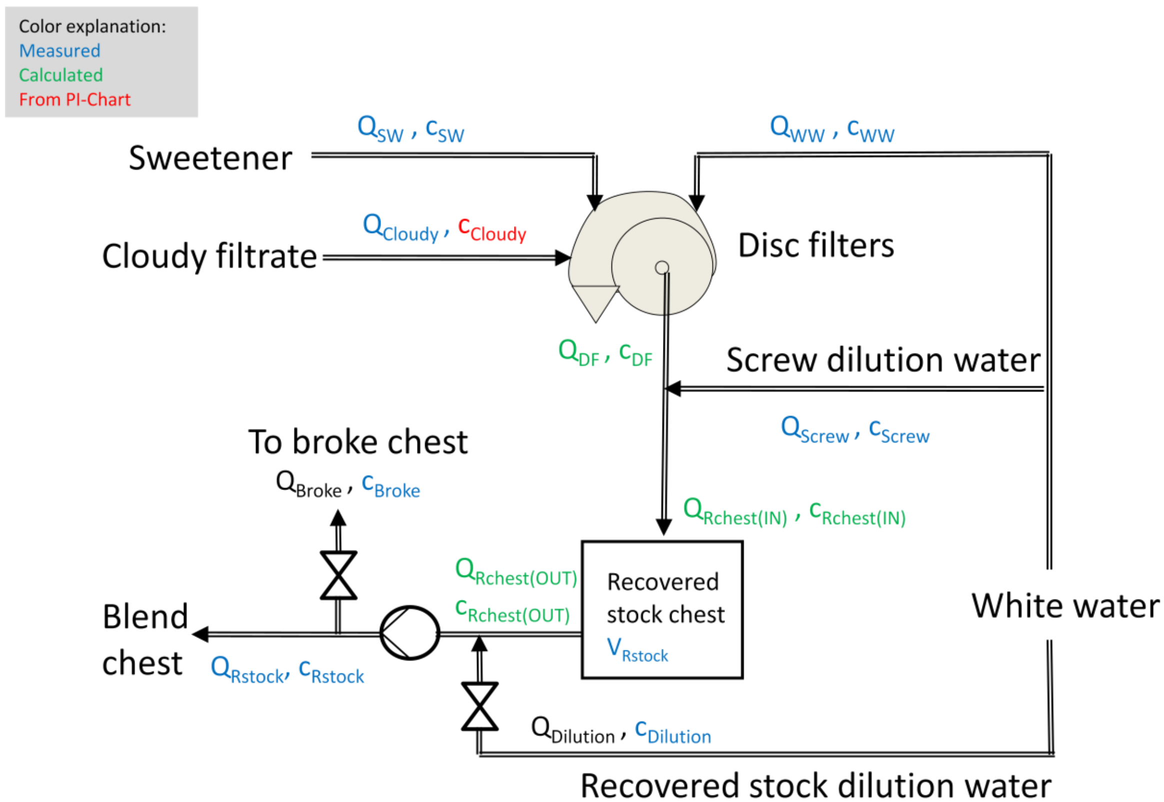

Figure 7.1. *Flows and consistencies in the disc filter area at the case mill. [9]*

The recovered stock chest level V_{Rstock} was constant during the examined cases so the flows $Q_{Rchest(IN)}$ and $Q_{Rchest(OUT)}$ are equal. Because there were no changes in the means of the measured consistencies and flows during the examined cases the consistencies $c_{Rchest(IN)}$ and $c_{Rchest(OUT)}$ can be approximated to be equal. The flow through the recovered stock chest can be calculated as

$$Q_{Rchest\,(IN)} = Q_{Rchest\,(OUT)} = Q_{Rstock} + Q_{Broke} - Q_{Dilution} \tag{7.1}$$

Recovered stock chest consistency can be calculated as

$$c_{Rchest(IN)} = c_{Rchest(OUT)} = \frac{Q_{Rstock}\, c_{Rstock} + Q_{Broke}\, c_{Broke} - Q_{Dilution}\, c_{Dilution}}{Q_{Rchest(IN)}} \tag{7.2}$$

And the similarly the consistency of the mass coming from the disc filters can be calculated as

$$c_{DF} = \frac{Q_{Rchest(IN)} c_{Rchest(IN)} - Q_{Screw}\, c_{Screw}}{Q_{Rchest(IN)} - Q_{Screw}} \tag{7.3}$$

The same consistency can be also calculated using the incoming flows to the disc filter and the filler distribution tracer test results presented in Section 7.1.1 (52% of filler propagates to the recovered stock). Using the assumptions that 100% of the sweetener propagates to the recovered stock and that all the solids in the white water and cloudy filtrate are either filler or fines and that fines propagate the same way filler does we get

$$c_{DF} = \frac{Q_{SW} c_{SW} + 0.52 * Q_{WW} c_{WW} + 0.52 * Q_{Cloudy}\, c_{Cloudy}}{Q_{Rchest(IN)} - Q_{Screw}} \tag{7.4}$$

The flows Q_{Broke} and $Q_{Dilution}$ are not measured and they have to be estimated. This is done using the measured openings of the valves controlling these flows. In the studied cases the assumption is used that the valves have linear operation on full range. The situation is studied with two cases. In case 1 the flow to the broke is estimated to be 200l/s and the dilution flow of the recovered stock is estimated to be 150l/s when the valves are fully opened. In case 1 the flow to the broke is estimated to be 100l/s and the dilution flow of the recovered stock is estimated to be 75l/s when the valves are fully opened. In Table 7.2 is presented consistency of the stock coming from the disc filters to the disc filter screw calculated for both cases. The values in the table are only rough estimations because so many assumptions had to be used in the calculations.

c_{DF}	Eq. 7.3	Eq. 7.4
Case 1	11.5 %	11.4 %
Case 2	9.0 %	9.1 %

Table 7.2. *Consistency of the stock coming from the disc filters to the disc filter screw.*

Time constant of the ideally mixed model for the recovered stock chest is studied using the same cases and the results are in Table 7.3.

	τ_{ideal}
Case 1	243 s
Case 2	221 s

Table 7.3. *Time constant of the ideally mixed recovered stock chest.*

The estimated ideal time constants are only rough estimations because so many assumptions had to be used in the calculations.

7.1.3 Flows in the stock preparation area

Figure 7.2 shows the volumetric flows in the stock preparation area. The colors in the picture represent where the values are taken from: blue values are measured, green values can be calculated using the known values and red values are looked from PI-chart of the case mill. Real values are not shown in the figure because they are confidential.

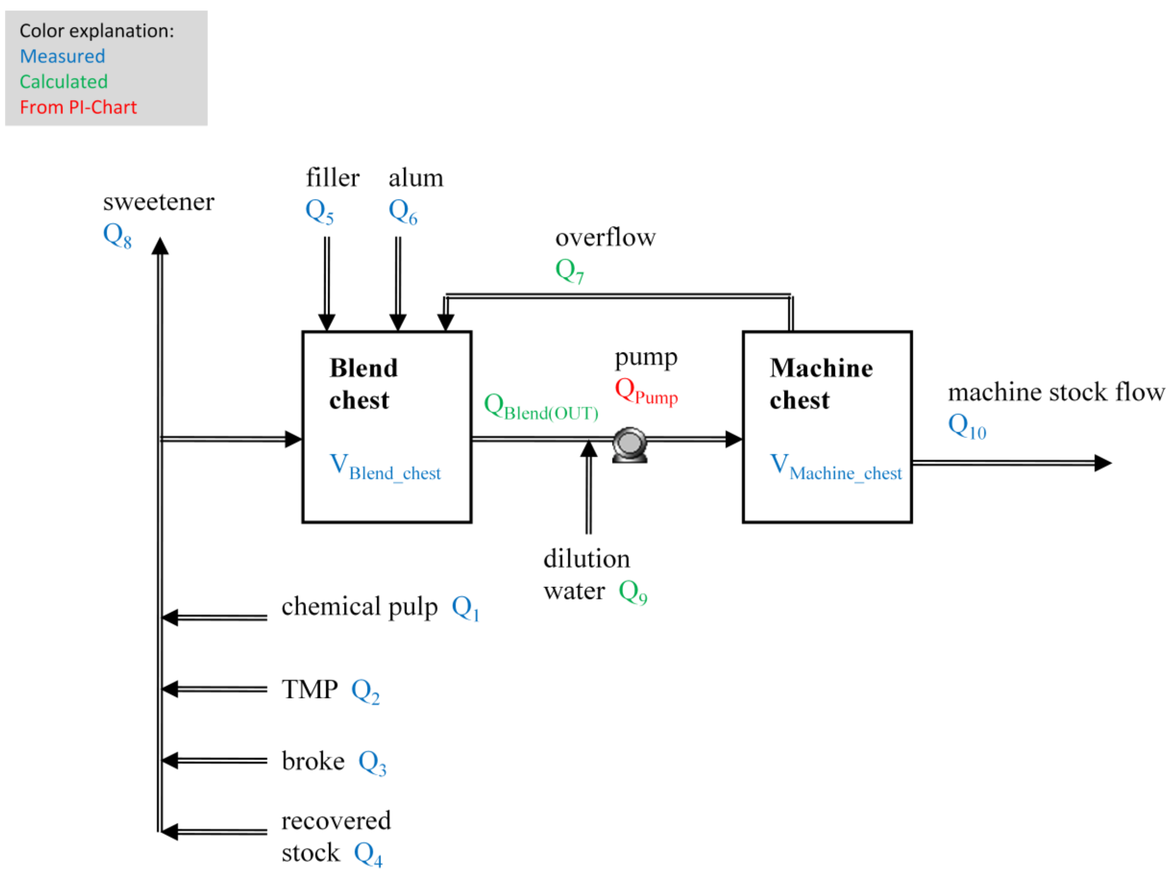

Figure 7.2.*Flows in the stock preparation area.*

Flows in the stock preparation area were studied from the data measured during the blend chest tracer tests. The pump between the blend chest and the machine chest has constant volumetric flow rate so the flow Q_{Pump} is constant. The blend chest level V_{Blend_chest} and the machine chest level $V_{Machine\_chest}$ were constant during the analyses. Thus the volumetric flow through blend chest can be calculated as

$$Q_{Blend\ (IN)} = Q_{Blend\ (OUT)} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 - Q_8 \tag{7.5}$$

Where the overflow from the machine chest Q_7 can be calculated as

$$Q_7 = Q_{Pump} - Q_{10} \tag{7.6}$$

Using the measured volume of the blend chest and the calculated flow through blend chest we get that the time constant of the ideally mixed blend chest is τ_{ideal} = 283 s.

7.2 Mixing dynamics of the chests

The blend chest mixing dynamics were studied with tracer tests described in Section 5.2 and analyzed results can be seen in Table 7.4.

	T1 (s)	T2 (s)	f (%)	τ1 (s)	τ2 (s)	τ3 (s)	J_N
First order transfer function	-	1	-	-	236	-	$2.59 \cdot 10^{-4}$
Non-ideal mixing	7	15	9.8	6	273	-	$7.63 \cdot 10^{-5}$
Non-ideal mixing with mixing in sequence	7	15	9.8	6	273	0	$7.54 \cdot 10^{-5}$

Table 7.4. *Blend chest parameters identified with data from tracer tests.*

The optimal value of the cost function of the non-ideal mixing models is less than one third of the optimal cost function value when first order transfer function is considered as the model. This indicates that the non-ideal mixing models describe the chest mixing behavior considerably more accurately. The largest difference between the models is at frequencies above 0.005Hz where the first order transfer function model corresponds very poorly to the data. Disturbances at the high frequencies are the most critical because consistency control does not attenuate these. Thus the first order transfer function model should not be used to describe the mixing behavior of the chest.

The optimal parameter values for the two non-ideal mixing models are quite identical. Thus there is no mixing in sequence in this chest. The identified model parameters show that approximately 10 % of the incoming flow is directly channeled through the chest almost without any mixing, i.e. almost as a plug flow. Dead times in the chest are relatively small but the ideal mixing model for the chest does not take these into account at all.

The ideally mixed volume of the blend chest can be calculated using the Equations 4.5, 4.6 and 4.7 when the ideal time constant calculated in Section 7.1.3 is known. The amount of fully mixed volume of the blend chest volume according to the tracer tests can be seen in Table 7.5. This indicates that 13-17% from the material in the chest is not in the mixing zone.

	V(fully mixed)
First order transfer function	83 %
Non-ideal mixing	87 %
Non-ideal mixing with mixing in sequence	87 %

Table 7.5. *Proportion of fully mixed volume from the blend chest volume.*

The recovered stock chest mixing dynamics were studied with tracer tests described in Section 5.2 and analyzed results can be seen in Table 7.6.

Feed to disc filter 1

	T1 (s)	T2 (s)	f (%)	τ1 (s)	τ2 (s)	τ3 (s)	J_N
First order transfer function	-	77	-	-	105	-	$2.22*10^{-5}$
Non-ideal mixing	95	78	6.7	10	110	-	$1.76*10^{-5}$
Non-ideal mixing with mixing in sequence	98	64	11.8	4	106	18	$1.68*10^{-5}$

Feed to disc filter 2

	T1 (s)	T2 (s)	f (%)	τ1 (s)	τ2 (s)	τ3	J_N
First order transfer function	-	56	-	-	94	-	$1.91*10^{-5}$
Non-ideal mixing	55	59	21.5	29	111	-	$9.29*10^{-6}$
Non-ideal mixing with mixing in sequence	51	60	20.3	22	107	5	$8.88*10^{-6}$

Table 7.6. *Recovered stock chest parameters identified with data from tracer tests.*

The inlet from the disc filter 1 to the recovered stock chest is fed further from the chest outlet than the inlet from the disc filter 2. This is manifested by the larger dead times for the disc filter 1 than for the disc filter 2. The dead times are big in both cases which can be a result of poor inlet locations in the chest. The inlet should feed directly to the mixing zone of the chest to provide smaller dead times. The amount of channeling is larger in the inlet from disc filter 2 which is closer to the outlet. According to the identified chest models approximately 20 % of the incoming flow from the disc filter 2 channels through the chest having only a moderate mixing. The amount of channeling should decrease if the inlet to the chest is fed directly to the mixing zone.

The ideally mixed volume of the recovered stock chest can be calculated using the Equations 4.5, 4.6 and 4.7 when the ideal time constants calculated for both cases in Section 7.1.2 are known. The amount of fully mixed volume of the recovered stock chest volume according to the tracer tests can be seen in Table 7.7.

V(fully mixed)	Feed to disc filter 1		Feed to disc filter 2	
	Case 1	Case 2	Case 1	Case 2
First order transfer function	43 %	39 %	47 %	43 %
Non-ideal mixing	42 %	36 %	47 %	39 %
Non-ideal mixing with mixing in sequence	46 %	37 %	50 %	41 %

Table 7.7. *Proportion of fully mixed volume from the recovered stock chest volume.*

Even though the flows estimated in the two cases are really rough estimates, still the fully mixed volume estimations show that the mixing in the recovered stock chest is not very effective. Large stagnant zones exist in the chest.

7.3 Improvements suggested for the case mill

The following observations of practical and immediate relevance were made when analyzing the data collected from the case mill:

- In a cascade control of main flows, the setpoint of cascade slave was provided by master measurement thus transferring the unnecessarily variations to the slave controller
- Malfunctioning control valve caused unnecessary variation in one of the main flows

Setpoint of recovered stock flow to the blend chest is in ratio with the sweetener flow, as explained in Section 3.1. The setpoint was in ratio with the sweetener flow measurement - rather than sweetener flow setpoint - and thus the variations in the sweetener flow propagated directly to the recovered stock flow. Figure 7.3 shows the recovered stock flow setpoint. During normal process operation COV of the recovered stock flow setpoint was 5.7 %. As a result the control performance was very poor.

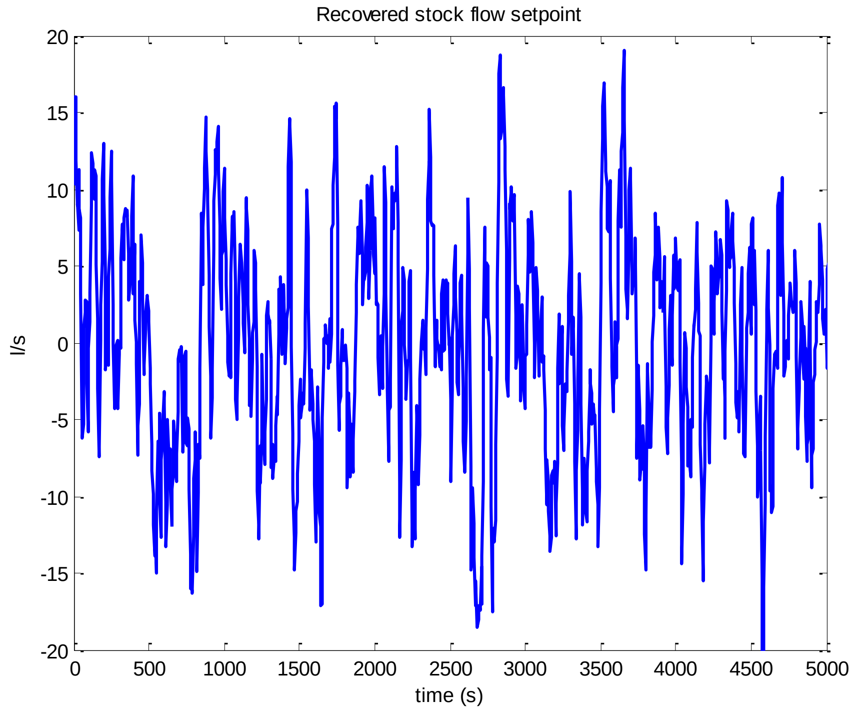

Figure 7.3. *Recovered stock flow setpoint. Average value is removed.*

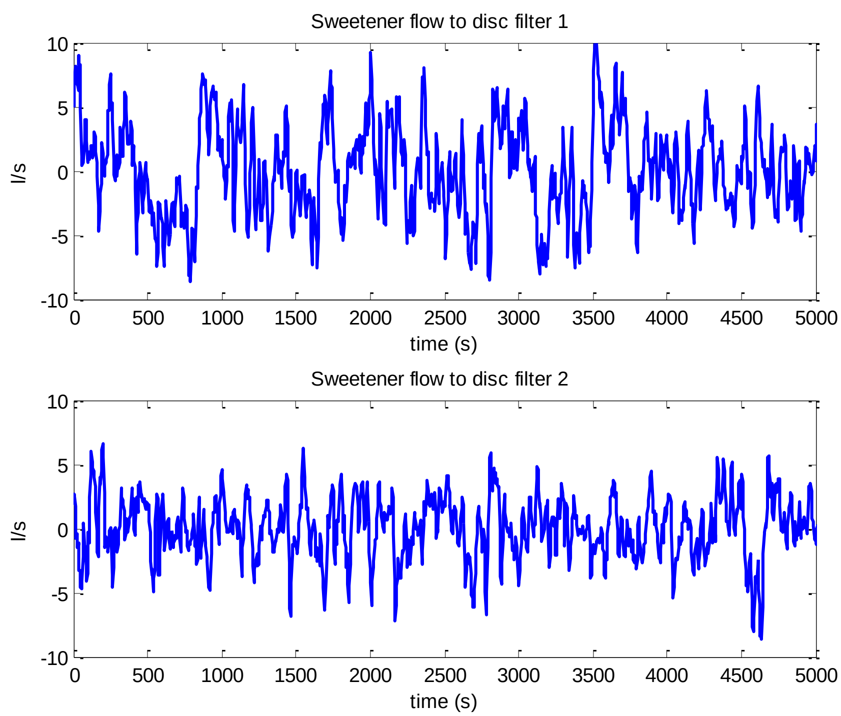

Figure 7.4. *Sweetener flows to the disc filters. Average values are removed.*

Variations in the sweetener flows to the disc filters were also relatively large as shown in Figure 7.4. The COV of the flow to the disc filter 1 was 9.2 % and of the flow to the disc filter 2 COV was 6.9 %. When the flow to the disc filter 1 was examined in detail it was observed that the valve controlling the flow has stiction when opened, see Figure 7.5. At the time instant marked with the red arrow in Figure 7.5 the control signal for the flow increased by several per cents while there is no recorded change in measurement. However, when the control signal exceeds a critical point the valve slips, i.e. opens too much. After the stick-slip event it takes in this case approximately 6 minutes to recover good control. This event occurred repeatedly in the sweetener flow to the disc filter 1.

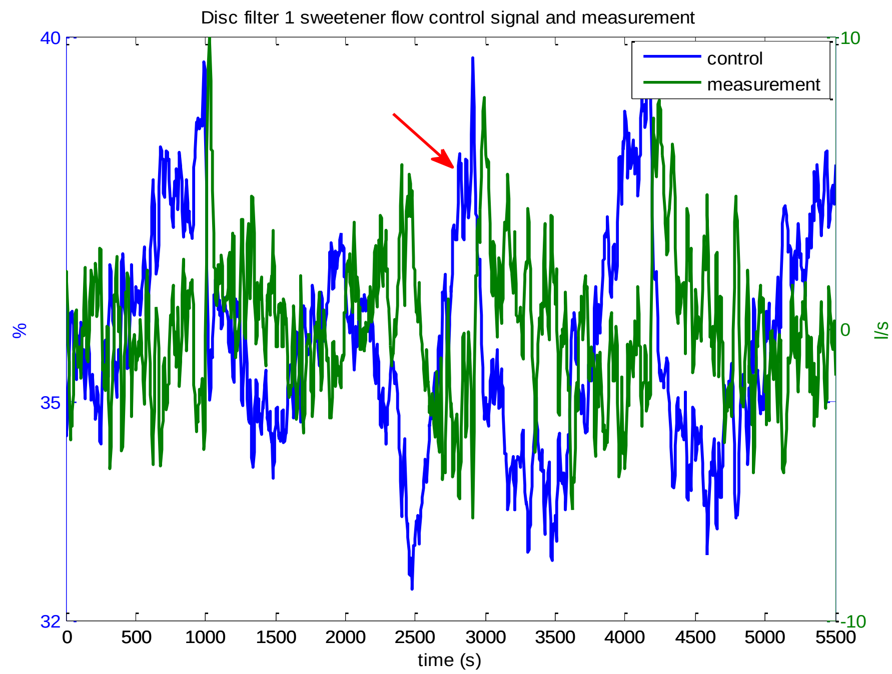

Figure 7.5. *Sweetener flow to the disc filter 1 control signal and measurement. Average value is removed from the measurement.*

The observations were reported to the case mill. The recovered stock flow control was changed to be in ratio with the sweetener flow setpoint. The malfunctioning control valve was replaced in the sweetener flow to the disc filter 1. Tables 7.8, 7.9 and 7.10 presents the coefficient of variations before and after the corrective actions. Paper machine is producing the same paper grade in both cases.

COV	White water consistency	White water ash consistency	White water ash content
Before	1,30 %	1,34 %	0,60 %
After	1,79 %	1,99 %	0,49 %
Difference	0.49 %	0.65 %	-0.11 %
Remaining variation in ratio to original	138 %	149 %	82 %

Table 7.8. *Coefficients of variations in the white water to the disc filters before and after the corrections made at the case mill.*

Incoming disturbances presented in Table 7.8, i.e. variations in the white water total consistency and ash consistency, are larger in the case studied after the corrections. These variables were not affected by the corrections.

COV	Sweetener flow to disc filter 1	Sweetener flow to disc filter 2
Before	9,2 %	6,9 %
After	7,4 %	7,1 %
Difference	-1.8 %	0.2 %
Remaining variation in ratio to original	80 %	103 %

Table 7.9. *Coefficients of variations in the sweetener flows to the disc filters before and after the corrections made at the case mill.*

Table 7.9 presents the disturbances in the sweetener flows to the disc filters before and after the corrections. The sweetener flow to disc filter 2 is not affected by the corrections. The disturbances caused by the malfunctioning control valve to the sweetener flow to disc filter 1 are now eliminated, resulting that the variation in sweetener flows to both disc filters are now at the same level. However, the variation in both sweetener flows is still rather large.

COV	Recovered stock flow	Recovered stock consistency	Recovered stock ash content
Before	5,0 %	1,33 %	6,4 %
After	1,2 %	0,56 %	2,2 %
Difference	-3.8 %	-0.77 %	-4.2 %
Remaining variation in ratio to original	24 %	42 %	34 %

Table 7.10. *Coefficients of variations in recovered stock from the disc filters before and after the corrections made at the case mill.*

The variations in the recovered stock are presented in Table 7.10. These variables were affected by the corrections and have their COVs considerably reduced. Even though the incoming variations in the white water to the disc filters are larger in the case studied after the corrections, the variation in the recovered stock flow to the blend chest has reduced by 75% and the variation in the total consistency by 60% from the situation before.

7.4 Total consistency and ash consistency disturbances

The variation in the total consistency of the recovered stock is shown in Figure 7.6 after the changes described at the Section 7.3 were made at the case mill. Measurement is made during normal operation at the case mill.

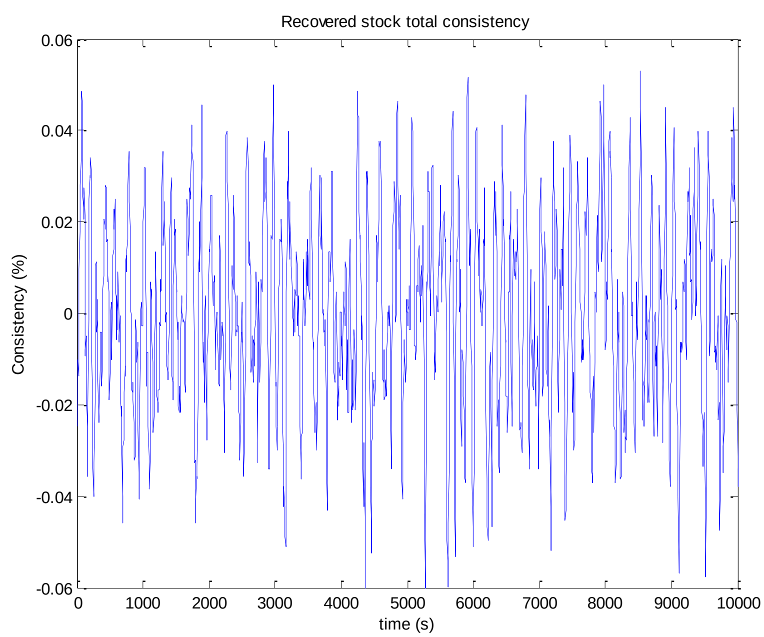

Figure 7.6. *Recovered stock total consistency. Average value is removed.*

Variation in the total consistency of the recovered stock appears to be within 0.1%-points peak to peak. However the consistency was measured with the BTG shear force meter and thus the ash consistency variation cannot be seen in it. The variation in the total consistency of the recovered stock can be approximated to consist of

$$c_{tot} = c_{fibres} + c_{ash} \tag{7.7}$$

The recovered stock ash content measured with the RM3 meter is approximately 50% during normal process operation. BTG was calibrated to show the total consistency as explained in Section 5.1. With the assumption that the recovered stock ash content was the same 50% during the calibration of the BTG meter the recovered stock total consistency measurement shows a variation of

$$c_{tot,BTG} = 2 * c_{fibres} \tag{7.8}$$

In Section 7.3 Table 7.10 shows the COV of the recovered stock ash content, which is approximately 4 times bigger than the COV of recovered stock total consistency. Thus it can be approximated that the variation in the recovered stock ash consistency is 4 times bigger than in the measured recovered stock total consistency. Using the Equations 7.7 and 7.8 we get the total consistency variation

$$c_{tot} \approx 0.5 * c_{tot,BTG} + 4 * c_{tot,BTG} = 4.5 * c_{tot,BTG} \tag{7.9}$$

The real variation in the recovered stock total consistency can thus be approximated to be 4.5 times bigger than the measured variation.

Figure 7.7 shows the amount of solids and filler coming with the recovered stock to the stock preparation and the amount of solids and filler leaving the stock preparation to the paper machine. Values are measured during normal operation at the case mill and they are mean values from measurements done for approximately 11 hours.

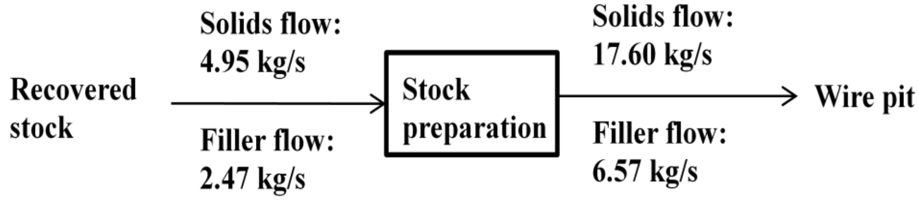

Figure 7.7. *Solids and filler flows from recovered stock to stock preparation and from stock preparation to wire pit.*

This shows that approximately 28 % of the solids and 38 % of the fillers in the machine stock come from the disc filters.

7.5 Cross-correlation and coherence between white water and recovered stock

The cross-correlation and coherence was studied between total consistency and ash content of white water and recovered stock. Ash content was used because the ash consistency of recovered stock could not be measured. Cross-correlation and coherence give us the linear correlation between the variations in the time and frequency domain.

Analysis was done to data sets measured during normal process operation when there were no user made changes on controller setpoints at the disc filter area. Data sets consist of 8000 points with 0.2Hz sample rate, thus the measurements were done for approximately 11 hours. The spectra for the coherence calculations were calculated with the Welch method with 50% overlapping. The minimum 4-term Blackman-Harris window function was used.

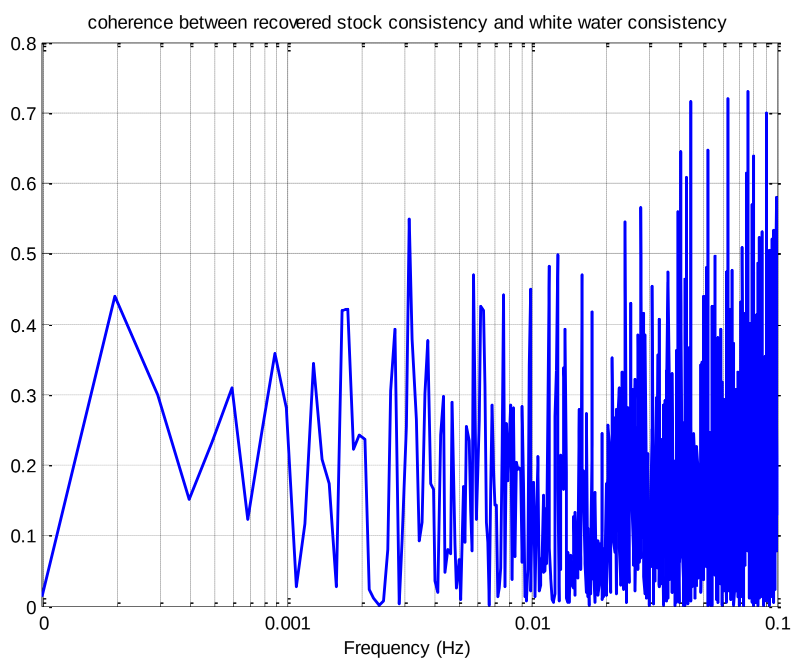

Figure 7.8. *Coherence between the recovered stock and white water total consistency.*

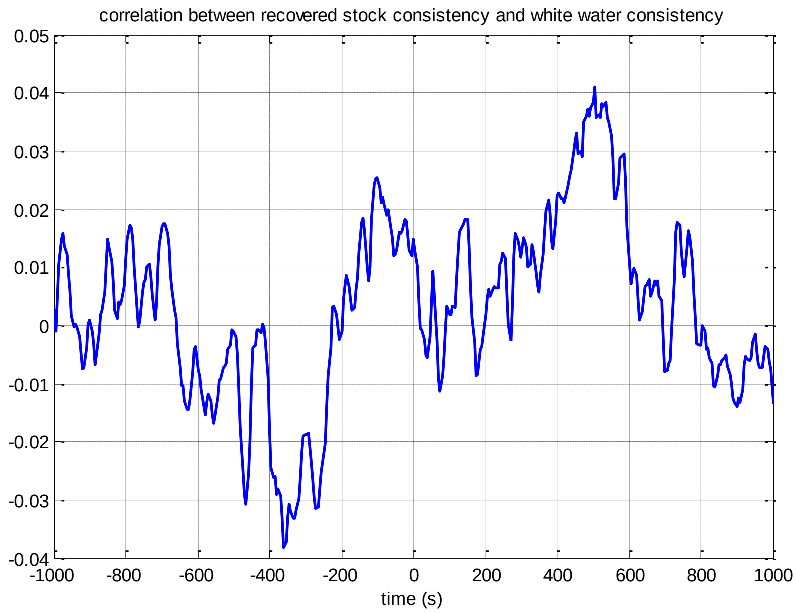

Figure 7.9. *Cross-correlation between the recovered stock and white water total consistency.*

In Figure 7.8 is the coherence between the recovered stock and white water total consistency and in Figure 7.9 is the cross-correlation between the recovered stock and white water total consistency. The coherence is weak and there seems to be no correlation between the two measured values.

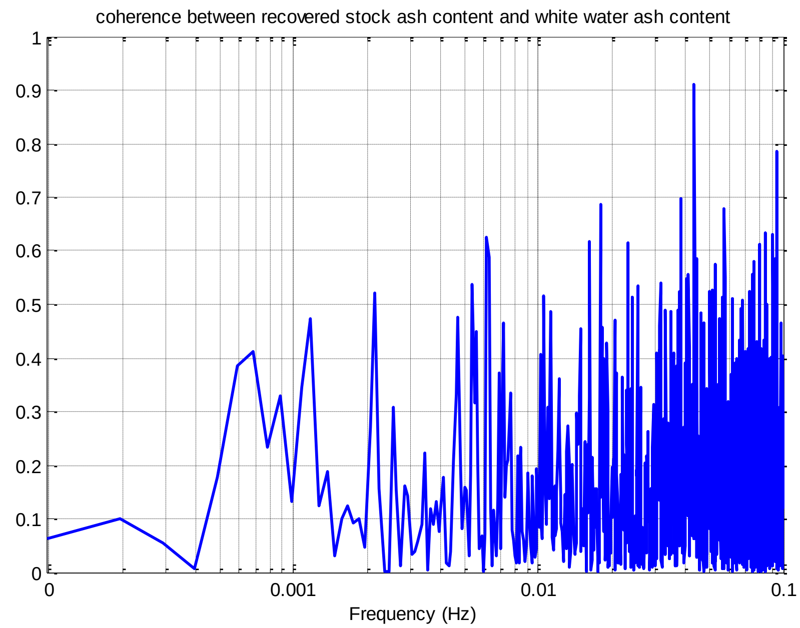

Figure 7.10. *Coherence between the recovered stock and white water ash content.*

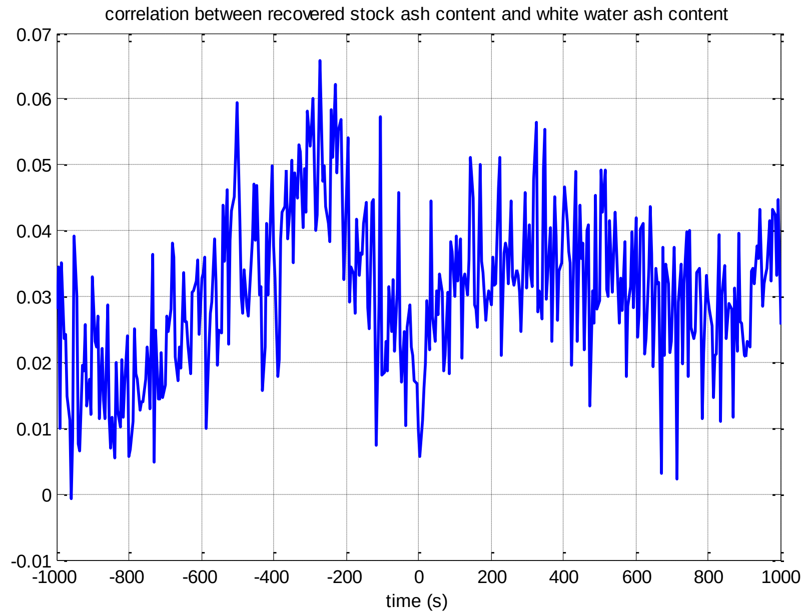

Figure 7.11. *Cross-correlation between the recovered stock and white water ash content.*

In Figure 7.10 is the coherence between the recovered stock and white water total consistency and in Figure 7.11 is the cross-correlation between the recovered stock and white water total consistency. The coherence is weak and there seems to be no correlation between the two measured values.

Weak coherence and the lack of correlation between two measurements mean that frequency response between them can’t be evaluated reliably. Thus transfer function estimation for between the recovered stock and white water total consistency and ash content is not needed.

8. Conclusions

The objective of this thesis was to study total consistency and ash consistency variations coming from disc filter. The data collected from the case mill was studied. It showed that there were simple but effective corrections to be done and they were reported to the case mill. After the improvements at the case mill were done, the variation in the recovered stock total consistency was within the limit of 0.1% peak to peak during normal process operation. However, this was measured with the BTG shear force meter which does not see the variations in the ash. The real variation in the recovered stock total consistency is approximately 4.5 times bigger than the measured variation. Measurements show that 28 % of the solids and 38 % of the fillers in the machine stock come from the disc filters during normal process operation at the case mill.

Filler propagation through disc filter was also studied. Tracer tests were executed to establish the distribution of filler through the disc filters. Results of these tests show that when going through disc filter approximately half of the filler in the white water propagates to the recovered stock and half to the filtrated waters.

The ability of the recovered stock and blend chests to attenuate disturbances was examined. Tracer tests were executed to study the mixing dynamics of the chests. Results show that non-ideal phenomena, channeling and stagnant zones, exist in the chests. Approximately 10% of the incoming flow goes through blend chest with almost no mixing at all. In the recovered stock this proportion was even 20% in the flow coming from disc filter 2. This indicates that fast variations can propagate through the chest. Dead times are also big in the recovered stock chest. Dead times should decrease if the inlets to the chest were led directly to the mixing zone. The fully mixed zone in the blend chest is only 83-87% of the chest volume which indicates big stagnant zones exist in the chest. The fully mixed zone in the recovered stock chest seems to be considerably smaller than in the blend chest, so even bigger stagnant zones exist in there.

Coherence and cross-correlation studies between the recovered stock and white water consistencies show that reliable frequency response can’t be estimated between them. Thus transfer function estimation is not needed.

8.1 Future research

Consistency disturbances due to disc filter were studied in this thesis at one case mill. The results could be compared with other paper mills where the controls in the fibre recovery area would be different and where the process conditions would differ. Analyses would give a lot more useful information if there were more measurements for consistencies and flows in the disc filter area. Comparison between different methods of controlling the fibre recovery should be done by either simulation or studying different case mills. In particular, the Optifeed concept introduced in Chapter 3 should be examined to discover the benefits it could bring.

At the case mill the reasons for large variations in the sweetener flows to disc filters should be inspected. Also the big dead times and stagnant zones in the recovered stock chest refer that the chest is not performing at the level it should.

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APPENDIX 1 : List of measured variables from the case mill (in Finnish).

Hierrelinja		
1	Hierretorni 1 pinta	%
2	Hierre 1 sakeus annostelusäiliöön, asetusarvo	%
3	Hierre 1 sakeus annostelusäiliöön, mittaus	%
4	Hierre 1 sakeus annostelusäiliöön, ohjaus	%
5	Häiriönpoistoaineen virtaus hierre 1:een, asetusarvo	ml/min
6	Häiriönpoistoaineen virtaus hierre 1:een, mittaus	ml/min
7	Häiriönpoistoaineen virtaus hierre 1:een, ohjaus	%
8	Valkaisemattoman hierteen osuus hierteestä	%
9	Hierteen 1 virtaus tornista, asetusarvo	l/s
10	Hierteen 1 virtaus tornista, mittaus	l/s
11	Hierteen 1 virtaus tornista, ohjaus	%
12	Hydrosulfidin virtaus hierre 1 annosteluun, asetusarvo	l/s
13	Hydrosulfidin virtaus hierre 1 annosteluun, mittaus	l/s
14	Hydrosulfidin virtaus hierre 1 annosteluun, ohjaus	%
15	Hierre 1 pH	pH
16	Hierretorni 2 pinta	%
17	Hierretornin kierrätysventtiili	xxx
18	Hierretornin purku hylkytorniin, sulkuventtiili	xxx
19	Hierre 2 sakeus annostelusäiliöön, asetusarvo	%
20	Hierre 2 sakeus annostelusäiliöön, mittaus	%
21	Hierre 2 sakeus annostelusäiliöön, ohjaus	%
22	Häiriönpoistoaineen virtaus hierre 2:een, asetusarvo	ml/min
23	Häiriönpoistoaineen virtaus hierre 2:een, mittaus	ml/min
24	Häiriönpoistoaineen virtaus hierre 2:een, ohjaus	%
25	Valkaistun hierteen osuus hierteestä	%
26	Hierteen 2 virtaus tornista, asetusarvo	l/s
27	Hierteen 2 virtaus tornista, mittaus	l/s
28	Hierteen 2 virtaus tornista, ohjaus	%
29	Hierre 2 pH	pH
30	Hierteen annostelusäiliön pinta, asetusarvo	%
31	Hierteen annostelusäiliön pinta, mittaus	%
32	Hierteen annostelusäiliön pinta, ohjaus	%
33	Hierteen annostelusakeus, asetusarvo	%
34	Hierteen annostelusakeus, mittaus	%
35	Hierteen annostelusakeus, ohjaus	%
36	Hierteen johtokyky	mS/m
37	Hierteen virtaus sekoitussäiliöön, asetusarvo	l/s
38	Hierteen virtaus sekoitussäiliöön, mittaus	l/s
39	Hierteen virtaus sekoitussäiliöön, ohjaus	%
Siistausmassa		
40	Siistausmassasihdin syöttövirtaus, asetusarvo	l/s
41	Siistausmassasihdin syöttövirtaus, mittaus	l/s
42	Siistausmassasihdin syöttövirtaus, ohjaus	%
43	Siistausmassasihdin rejektivirtaus, asetusarvo	l/s
44	Siistausmassasihdin rejektivirtaus, mittaus	l/s
45	Siistausmassasihdin rejektivirtaus, ohjaus	%
46	Siistausmassan annostelusäiliön pinta, asetusarvo	%
47	Siistausmassan annostelusäiliön pinta, mittaus	%
48	Siistausmassan annostelusäiliön pinta, ohjaus	%
49	Siistausmassan annostelusakeus, asetusarvo	%
50	Siistausmassan annostelusakeus, mittaus	%
51	Siistausmassan annostelusakeus, ohjaus	%
52	Siistausmassan virtaus PKy	l/s
53	Siistausmassan virtaus sekoitussäiliöön, asetusarvo	l/s
54	Siistausmassan virtaus sekoitussäiliöön, mittaus	l/s
55	Siistausmassan virtaus sekoitussäiliöön, ohjaus	%
56	Siistausmassan johtokyky	mS/m
Sellulinja		
57	Sellutornin pinta	%
58	Sellutornin purkusakeus annostelusäiliöön, asetusarvo	%
59	Sellutornin purkusakeus annostelusäiliöön, mittaus	%
60	Sellutornin purkusakeus annostelusäiliöön, ohjaus	%
61	Sellutornin laimennusvirtaus	l/s
62	Sellun virtaus annostelusäiliöön	l/s
63	Sellun annostelusäiliön pinta, asetusarvo	%
64	Sellun annostelusäiliön pinta, mittaus	%

65	Sellun annostelusäiliön pinta, ohjaus	%
66	Sellu nokkakyyppiin, sulkuventtiili	xxx
67	Sellu nokkakyyppiin, huuhteluventtiili	xxx
68	Sellun annostelusakeus (jauhatukseen), asetusarvo	%
69	Sellun annostelusakeus (jauhatukseen), mittaus	%
70	Sellun annostelusakeus (jauhatukseen), ohjaus	%
71	Sellun annostelusakeuden laimennusvirtaus	l/s
72	Sellun kuiva-ainevirtaus	t/h
73	Sellulinjan jauhimien ominaisenergia, asetusarvo	kWh/t
74	Sellulinjan jauhimien ominaisenergia, mittaus	kWh/t
75	Sellujauhin 1 ohitusventtiili	xxx
76	Sellujauhin 1 syöttöventtiili	xxx
77	Sellujauhin 1 poistoventtiili	xxx
78	Sellujauhin 1 paineenpoistoventtiili	xxx
79	Sellujauhin 1 syöttöpaine	kPa
80	Sellujauhin 1 kokonaisteho	kW
81	Sellujauhin 1 jauhatusteho, asetusarvo	kW
82	Sellujauhin 1 jauhatusteho, mittaus	kW
83	Sellujauhin 1 jauhatusteho, ohjaus	kW
84	Sellujauhin 1 osuus linjan ominaisenergiasta	%
85	Sellujauhin 1 ominaisenergia, asetusarvo	kWh/t
86	Sellujauhin 1 ominaisenergia, mittaus	kWh/t
87	Sellujauhin 1 terävärähtely	%
88	Sellujauhin 1 teräasento	mm
89	Sellujauhin 2 ohitusventtiili	xxx
90	Sellujauhin 2 syöttöventtiili	xxx
91	Sellujauhin 2 poistoventtiili	xxx
92	Sellujauhin 2 paineenpoistoventtiili	xxx
93	Sellujauhin 2 syöttöpaine	kPa
94	Sellujauhin 2 kokonaisteho	kW
95	Sellujauhin 2 jauhatusteho, asetusarvo	kW
96	Sellujauhin 2 jauhatusteho, mittaus	kW
97	Sellujauhin 2 jauhatusteho, ohjaus	kW
98	Sellujauhin 2 osuus linjan ominaisenergiasta	%
99	Sellujauhin 2 ominaisenergia, asetusarvo	kWh/t
100	Sellujauhin 2 ominaisenergia, mittaus	kWh/t
101	Sellujauhin 2 terävärähtely	%
102	Sellujauhin 2 teräasento	mm
103	Sellujauhin 3 ohitusventtiili	xxx
104	Sellujauhin 3 syöttöventtiili	xxx
105	Sellujauhin 3 poistoventtiili	xxx
106	Sellujauhin 3 paineenpoistoventtiili	xxx
107	Sellujauhin 3 syöttöpaine	kPa
108	Sellujauhin 3 kokonaisteho	kW
109	Sellujauhin 3 jauhatusteho, asetusarvo	kW
110	Sellujauhin 3 jauhatusteho, mittaus	kW
111	Sellujauhin 3 jauhatusteho, ohjaus	kW
112	Sellujauhin 3 osuus linjan ominaisenergiasta	%
113	Sellujauhin 3 ominaisenergia, asetusarvo	kWh/t
114	Sellujauhin 3 ominaisenergia, mittaus	kWh/t
115	Sellujauhin 3 terävärähtely	%
116	Sellujauhin 3 teräasento	mm
117	Sellun jauhatus freeness, asetusarvo	ml
118	Sellun jauhatus freeness, mittaus	ml
119	Sellun jauhatus freeness, ohjaus	%
120	Sellulinjan paine (kierrätys), asetusarvo	kPa
121	Sellulinjan paine (kierrätys), mittaus	kPa
122	Sellulinjan paine (kierrätys), ohjaus	%
123	Sellun virtaus sekoitussäiliöön, asetusarvo	l/s
124	Sellun virtaus sekoitussäiliöön, mittaus	l/s
125	Sellun virtaus sekoitussäiliöön, ohjaus	%
126	Sellun annostelun ohitusvirtaus (hylyn annosteluun), asetusarvo	l/s
127	Sellun annostelun ohitusvirtaus (hylyn annosteluun), mittaus	l/s
128	Sellun annostelun ohitusvirtaus (hylyn annosteluun), ohjaus	%
129	Sellun pH	pH
130	Sellun johtokyky	mS/m
131	Sellun annostelun ohitusvirtaus nokkakyyppiin, sulkuventtiili	xxx
132	Sellun annostelun ohitusvirtaus nokkakyyppiin, huuhteluventtiili	xxx
133	Sellulinjan huuhteluventtiili	xxx
Hylyn keruu		
134	Reunanauhapulpperin pinta, asetusarvo	%
135	Reunanauhapulpperin pinta, mittaus	%
136	Reunanauhapulpperin pinta, ohjaus	%
137	Reunanauhapulpperin pinta, venttiili 1 (nokkakyyppiin)	%
138	Reunanauhapulpperin pinta, venttiili 2 (kierrätys)	%
139	Reunanauhapulpperin imu, asetusarvo	kPa
140	Reunanauhapulpperin imu, mittaus	kPa
141	Reunanauhapulpperin imu, ohjaus	%

142	Reunanauhapulpperin sakeus, asetusarvo	%
143	Reunanauhapulpperin sakeus, mittaus	%
144	Reunanauhapulpperin sakeus, ohjaus	%
145	Reunanauhapulpperin pH	pH
146	Reunanauhapulpperin tyhjennys PKx	xxx
147	Reunanauhapulpperin tyhjennys PKy	xxx
148	Pituusleikkuri 1 esinauha reunanauhapulpperiin, sulkuventtiili	xxx
149	Pituusleikkuri 1 reunanauha reunanauhapulpperiin, sulkuventtiili	xxx
150	Pituusleikkuri 2 esinauha reunanauhapulpperiin, sulkuventtiili	xxx
151	Pituusleikkuri 2 reunanauha reunanauhapulpperiin, sulkuventtiili	xxx
152	Uudelleenrullaimen reunanauhan imulinja, sulkuventtiili	xxx
153	Pituusleikkuri 1 esinauha reunanauhapulpperiin, kuristusventtiili	%
154	Pituusleikkuri 1 reunanauha reunanauhapulpperiin, kuristusventtiili	%
155	Pituusleikkuri 2 esinauha reunanauhapulpperiin, kuristusventtiili	%
156	Pituusleikkuri 2 reunanauha reunanauhapulpperiin, kuristusventtiili	%
157	Uudelleenrullaimen reunanauhan imulinja, kuristusventtiili	%
158	Hylkyrullapulpperin tyhjennys PKx nokkakyyppiin	xxx
159	Pituusleikkuri 62 pulpperin pinta, asetusarvo	%
160	Pituusleikkuri 62 pulpperin pinta, mittaus	%
161	Pituusleikkuri 62 pulpperin pinta, ohjaus	%
162	Pituusleikkuri 62 pulpperin pinta, venttiili 1 (nokkakyyppiin)	%
163	Pituusleikkuri 62 pulpperin pinta, venttiili 2 (kierrätys)	%
164	Pituusleikkuri 62 pulpperin sakeus, asetusarvo	%
165	Pituusleikkuri 62 pulpperin sakeus, mittaus	%
166	Pituusleikkuri 62 pulpperin sakeus, ohjaus	%
167	Pituusleikkuri 62 luiskavesiventtiili	%
168	Pituusleikkuri 62 laimennusvesiventtiili	%
169	Pituusleikkuri 62 puhaltimen imuventtiili	xxx
170	Pituusleikkuri 61 pulpperin pinta, asetusarvo	%
171	Pituusleikkuri 61 pulpperin pinta, mittaus	%
172	Pituusleikkuri 61 pulpperin pinta, ohjaus	%
173	Pituusleikkuri 61 pulpperin pinta, venttiili 1 (nokkakyyppiin)	%
174	Pituusleikkuri 61 pulpperin pinta, venttiili 2 (kierrätys)	%
175	Pituusleikkuri 61 pulpperin sakeus, asetusarvo	%
176	Pituusleikkuri 61 pulpperin sakeus, mittaus	%
177	Pituusleikkuri 61 pulpperin sakeus, ohjaus	%
178	Pituusleikkuri 61 luiskavesiventtiili	%
179	Pituusleikkuri 61 laimennusvesiventtiili	%
180	Pituusleikkuri 61 puhaltimen imuventtiili	xxx
181	SK-pulpperi 2 pinta, asetusarvo	%
182	SK-pulpperi 2 pinta, mittaus	%
183	SK-pulpperi 2 pinta, ohjaus	%
184	SK-pulpperi 2 sakeus, asetusarvo	%
185	SK-pulpperi 2 sakeus, mittaus	%
186	SK-pulpperi 2 sakeus, ohjaus	%
187	SK-pulpperi 1 pinta, asetusarvo	%
188	SK-pulpperi 1 pinta, mittaus	%
189	SK-pulpperi 1 pinta, ohjaus	%
190	SK-pulpperi 1 sakeus, asetusarvo	%
191	SK-pulpperi 1 sakeus, mittaus	%
192	SK-pulpperi 1 sakeus, ohjaus	%
193	Konepulpperin pinta, asetusarvo	%
194	Konepulpperin pinta, mittaus	%
195	Konepulpperin pinta, ohjaus	%
196	Konepulpperin pinta, venttiili 1 (nokkakyyppiin)	%
197	Konepulpperin pinta, venttiili 1 (kierrätys)	%
198	Konepulpperin sakeus, asetusarvo	%
199	Konepulpperin sakeus, mittaus	%
200	Konepulpperin sakeus, ohjaus	%
201	Konepulpperin laimennusvesivirtaus, asetusarvo	l/s
202	Konepulpperin laimennusvesivirtaus, mittaus	l/s
203	Konepulpperin laimennusvesivirtaus, ohjaus	%
204	Konepulpperin laimennusvesivirtaus, venttiilin ohjaus katkossa	%
205	Konepulpperin päänvientisuihkuventtiili, asetusarvo	%
206	Konepulpperin päänvientisuihkuventtiili, mittaus	%
207	Konepulpperin luiskavesiventtiili katkoarvo, asetusarvo	%
208	Konepulpperin luiskavesiventtiili katkoarvo, mittaus	%
209	Konepulppperi tappovesiventtiili, asetusarvo	%
210	Konepulppperi tappovesiventtiili, mittaus	%
211	Puristinpulpperi 2 pinta, asetusarvo	%
212	Puristinpulpperi 2 pinta, mittaus	%
213	Puristinpulpperi 2 pinta, ohjaus	%
214	Puristinpulpperi 2 pinta, venttiili 1 (nokkakyyppiin)	%
215	Puristinpulpperi 2 pinta, venttiili 2 (kierrätys)	%
216	Puristinpulpperi 2 sakeus	%
217	Puristinpulpperi 2 pesuventtiili HP	xxx
218	Puristinpulpperi 2 pesuventtiili KP	xxx

219	Puristinpulpperi 2 puhaltimen imuventtiili	xxx
220	Puristinpulpperi 2 päänvientisuihkuventtiili, asetusarvo	%
221	Puristinpulpperi 2 päänvientisuihkuventtiili, mittaus	%
222	Puristinpulpperi 2 laimennusventtiili (katko), asetusarvo	%
223	Puristinpulpperi 2 laimennusventtiili (katko), mittaus	%
224	Puristinpulpperi 1 pinta, asetusarvo	%
225	Puristinpulpperi 1 pinta, mittaus	%
226	Puristinpulpperi 1 pinta, ohjaus	%
227	Puristinpulpperi 1 pinta, venttiili 1 (nokkakyyppiin)	%
228	Puristinpulpperi 1 pinta, venttiili 2 (kierrätys)	%
229	Puristinpulpperi 1 sakeus	%
230	Puristinpulpperi 1 puhaltimen imuventtiili	xxx
231	Puristinpulpperi 1 laimennusvesivirtaus, asetusarvo	l/s
232	Puristinpulpperi 1 laimennusvesivirtaus, mittaus	l/s
233	Puristinpulpperi 1 laimennusvesivirtaus, ohjaus	%
234	Puristinpulpperi 1 laimennusvesivirtaus, venttiili	%
235	Nokkakyypin pinta, asetusarvo	%
236	Nokkakyypin pinta, mittaus	%
237	Nokkakyypin pinta, ohjaus	%
238	Nokkakyypin pinta, venttiili 1 (pumppu 2)	%
239	Nokkakyypin pinta, venttiili 2 (pumppu 1)	%
240	Nokkakyypin pinta, venttiili 3 (kierrätys)	%
241	Nokkakyypin sakeus	%
242	Nokkakyypin laimennusventtiili (katko), asetusarvo	%
243	Nokkakyypin laimennusventtiili (katko), mittaus	%
244	Nokkakyypin pumppu 1	xxx
245	Nokkakyypin pumppu 2	xxx
Hylkylinja		
246	Hylkytornin pinta	%
247	Hylyn syöttö nokkakyypistä hylkytorniin, asetusarvo	%
248	Hylyn syöttö nokkakyypistä hylkytorniin, mittaus	%
249	Hylyn syöttö nokkakyypistä hylkytorniin, ohjaus	%
250	Hylyn syöttö nokkakyypistä hierretorniin, kuristusventtiili	%
251	Hylkytornin purkusakeus (hylyn lajittelun 1. portaan syöttö), asetusarvo	%
252	Hylkytornin purkusakeus (hylyn lajittelun 1. portaan syöttö), mittaus	%
253	Hylkytornin purkusakeus (hylyn lajittelun 1. portaan syöttö), ohjaus	%
254	Hylyn lajittelun 1. portaan syöttöpaine, asetusarvo	kPa
255	Hylyn lajittelun 1. portaan syöttöpaine, mittaus	kPa
256	Hylyn lajittelun 1. portaan syöttöpaine, ohjaus	%
257	PKy hylky hylyn lajittelun 1. portaan syöttöön, kuristusventtiili	%
258	Hylyn lajittelun 1. portaan ilmanpoistoventtiili	xxx
259	Hylyn lajittelun 1. portaan rejekti rejektisäiliöön, asetusarvo	%
260	Hylyn lajittelun 1. portaan rejekti rejektisäiliöön, mittaus	%
261	Hylyn lajittelun 1. portaan rejekti rejektisäiliöön, ohjaus	%
262	Hylyn lajittelun 1. portaan paine-ero, syöttö - rejekti	kPa
263	Hylyn lajittelun 1. portaan paine-ero, aksepti - rejekti	kPa
264	Hylyn lajittelun 1. portaan laimennusvesiventtiili	%
265	Hylyn lajittelun 1. portaan akseptivirtaus hylyn saostimelle, asetusarvo	l/s
266	Hylyn lajittelun 1. portaan akseptivirtaus hylyn saostimelle, mittaus	l/s
267	Hylyn lajittelun 1. portaan akseptivirtaus hylyn saostimelle, ohjaus	%
268	Hylyn lajittelun 1. portaan rejektivirtaus 2. portaan syöttösäiliöön, asetusarvo	l/s
269	Hylyn lajittelun 1. portaan rejektivirtaus 2. portaan syöttösäiliöön, mittaus	l/s
270	Hylyn lajittelun 1. portaan rejektivirtaus 2. portaan syöttösäiliöön, ohjaus	%
271	Hylyn lajittelun 2. portaan syöttösäiliön pinta, asetusarvo	%
272	Hylyn lajittelun 2. portaan syöttösäiliön pinta, mittaus	%
273	Hylyn lajittelun 2. portaan syöttösäiliön pinta, ohjaus	%
274	Hylyn lajittelun 2. portaan syöttösakeus, asetusarvo	%
275	Hylyn lajittelun 2. portaan syöttösakeus, mittaus	%
276	Hylyn lajittelun 2. portaan syöttösakeus, ohjaus	%
277	Hylyn lajittelun 2. portaan paine-ero, aksepti - rejekti	kPa
278	Hylyn lajittelun 2. portaan laimennusvesiventtiili	%
279	Hylyn lajittelun 2. portaan akseptivirtaus	l/s
280	Hylyn lajittelun 2. portaan rejektivirtaus, asetusarvo	l/s
281	Hylyn lajittelun 2. portaan rejektivirtaus, mittaus	l/s
282	Hylyn lajittelun 2. portaan rejektivirtaus, ohjaus	%
283	Hylyn kokonaisvirtaus hylkysaostimelle	l/s
284	Hylyn lajittelun 3. portaan syöttösäiliön pinta, asetusarvo	%
285	Hylyn lajittelun 3. portaan syöttösäiliön pinta, mittaus	%
286	Hylyn lajittelun 3. portaan syöttösäiliön pinta, ohjaus	%
287	Hylyn lajittelun 3. portaan syöttösakeus, asetusarvo	%
288	Hylyn lajittelun 3. portaan syöttösakeus, mittaus	%
289	Hylyn lajittelun 3. portaan syöttösakeus, ohjaus	%
290	Hylyn lajittelun 3. portaan paine-ero, syöttö - aksepti	kPa
291	Hylyn lajittelun 3. portaan huuhteluventtiili	xxx
292	Hylyn lajittelun 3. portaan akseptivirtaus 2. portaan syöttösäiliöön	l/s
293	Hylyn lajittelun 3. portaan rejektin virtaus 4. portaan syöttöön, asetusarvo	l/s
294	Hylyn lajittelun 3. portaan rejektin virtaus 4. portaan syöttöön, mittaus	l/s

295	Hylyn lajittelun 3. portaan rejektin virtaus 4. portaan syöttöön, ohjaus	%
296	Hylyn lajittelun 4. portaan laimennusvesivirtaus, asetusarvo	l/s
297	Hylyn lajittelun 4. portaan laimennusvesivirtaus, mittaus	l/s
298	Hylyn lajittelun 4. portaan laimennusvesivirtaus, ohjaus	%
299	Hylyn lajittelun 4. portaan syöttöpaine	kPa
300	Hylyn lajittelun 4. portaan akseptipaine, asetusarvo	kPa
301	Hylyn lajittelun 4. portaan akseptipaine, mittaus	kPa
302	Hylyn lajittelun 4. portaan akseptipaine, ohjaus	%
303	Hylyn lajittelun 4. portaan paine-ero, syöttö - aksepti	kPa
304	Hylyn lajittelun 4. portaan akseptivirtaus	l/s
305	Hylyn lajittelun 4. portaan rejektivirtaus, asetusarvo	l/s
306	Hylyn lajittelun 4. portaan rejektivirtaus, mittaus	l/s
307	Hylyn lajittelun 4. portaan rejektivirtaus, ohjaus	%
308	Hylyn rejektin keräilysäiliön pinta, asetusarvo	%
309	Hylyn rejektin keräilysäiliön pinta, mittaus	%
310	Hylyn rejektin keräilysäiliön pinta, ohjaus	%
311	Hylkysaostimen laimennusvirtaus (sameasuodos), asetusarvo	l/s
312	Hylkysaostimen laimennusvirtaus (sameasuodos), mittaus	l/s
313	Hylkysaostimen laimennusvirtaus (sameasuodos), ohjaus	%
314	Hylkysaostimen syöttösakeus	%
315	Hylkysaostimen ohitusventtiili (annostelusäiliöön)	%
316	Hylkysaostimen syöttövirtaus [t/h]	t/h
317	Hylkysaostimen syöttövirtaus [kg/s]	kg/s
318	Hylkysaostimen syöttövirtaus [l/s]	l/s
319	Hylkysaostimen pinta, asetusarvo	%
320	Hylkysaostimen pinta, mittaus	%
321	Hylkysaostimen pinta, ohjaus	%
322	Hylkysaostimen laimennusvirtaus, asetusarvo	l/s
323	Hylkysaostimen laimennusvirtaus, mittaus	l/s
324	Hylkysaostimen laimennusvirtaus, ohjaus	%
325	Hylkysaostimen kirkassuodoksen imujalan alipaine	kPa
326	Hylkysaostimen nopeus	r/min
327	Hylkysaostimen momentti	%
328	Hylkysaostimen suihkuvesiventtiili	xxx
329	Hylkysaostimen 1. pesuventiili	xxx
330	Hylkysaostimen 2. pesuventiili	xxx
331	Hylkysaostimen 3. pesuventiili	xxx
332	Hylyn annostelusäiliön pinta, asetusarvo	%
333	Hylyn annostelusäiliön pinta, mittaus	%
334	Hylyn annostelusäiliön pinta, ohjaus	%
335	Saostetun hylyn sakeus annostelusäiliöstä hylkytorniin	%
336	Hylyn annostelusakeus, asetusarvo	%
337	Hylyn annostelusakeus, mittaus	%
338	Hylyn annostelusakeus, ohjaus	%
339	Häiriönpoistoaineen virtaus hylyn annosteluun, asetusarvo	ml/min
340	Häiriönpoistoaineen virtaus hylyn annosteluun, mittaus	ml/min
341	Häiriönpoistoaineen virtaus hylyn annosteluun, ohjaus	%
342	Hylyn annosteluvirtaus sekoitussäiliöön, asetusarvo	l/s
343	Hylyn annosteluvirtaus sekoitussäiliöön, mittaus	l/s
344	Hylyn annosteluvirtaus sekoitussäiliöön, ohjaus	%
345	Hylyn pH	pH
346	Hylyn johtokyky	mS/m
Kiekkosuotimet		
347	Apumassan virtaus kiekkosuodin 1:lle, asetusarvo	l/s
348	Apumassan virtaus kiekkosuodin 1:lle, mittaus	l/s
349	Apumassan virtaus kiekkosuodin 1:lle, ohjaus	%
350	Nollaveden virtaus kiekkosuodin 1:lle, asetusarvo	l/s
351	Nollaveden virtaus kiekkosuodin 1:lle, mittaus	l/s
352	Nollaveden virtaus kiekkosuodin 1:lle, ohjaus	%
353	Nollaveden virtaus kiekkosuodin 1 ruuville, asetusarvo	l/s
354	Nollaveden virtaus kiekkosuodin 1 ruuville, mittaus	l/s
355	Nollaveden virtaus kiekkosuodin 1 ruuville, ohjaus	%
356	Kiekkosuodin 1 nopeusohje	%
357	Kiekkosuodin 1 pinta, asetusarvo	%
358	Kiekkosuodin 1 pinta, mittaus	%
359	Kiekkosuodin 1 pinta, ohjaus	%
360	Kiekkosuodin 1 kirkassuodoksen alipaine	kPa
361	Sameasuodoksen virtaus kiekkosuodin 1:lle	l/s
362	Apumassan virtaus kiekkosuodin 2:lle, asetusarvo	l/s
363	Apumassan virtaus kiekkosuodin 2:lle, mittaus	l/s
364	Apumassan virtaus kiekkosuodin 2:lle, ohjaus	%
365	Nollaveden virtaus kiekkosuodin 2:lle, asetusarvo	l/s
366	Nollaveden virtaus kiekkosuodin 2:lle, mittaus	l/s
367	Nollaveden virtaus kiekkosuodin 2:lle, ohjaus	%
368	Nollaveden virtaus kiekkosuodin 2 ruuville, asetusarvo	l/s
369	Nollaveden virtaus kiekkosuodin 2 ruuville, mittaus	l/s
370	Nollaveden virtaus kiekkosuodin 2 ruuville, ohjaus	%

371	Kiekkosuodin 2 nopeusohje	%
372	Kiekkosuodin 2 pinta, asetusarvo	%
373	Kiekkosuodin 2 pinta, mittaus	%
374	Kiekkosuodin 2 pinta, ohjaus	%
375	Kiekkosuodin 2 kirkassuodoksen alipaine	kPa
376	Sameasuodoksen virtaus kiekkosuodin 2:lle	l/s
377	Suodosmassasäiliön pinta, asetusarvo	%
378	Suodosmassasäiliön pinta, mittaus	%
379	Suodosmassasäiliön pinta, ohjaus	%
380	Suodosmassan sakeus, asetusarvo	%
381	Suodosmassan sakeus, mittaus	%
382	Suodosmassan sakeus, ohjaus	%
383	Suodosmassan virtaus sekoitussäiliöön, asetusarvo	l/s
384	Suodosmassan virtaus sekoitussäiliöön, mittaus	l/s
385	Suodosmassan virtaus sekoitussäiliöön, ohjaus	%
386	Sameasuodossäiliön pinta, asetusarvo	%
387	Sameasuodossäiliön pinta, mittaus	%
388	Sameasuodossäiliön pinta, ohjaus	%
389	Sameasuodossäiliön pinta, venttiili 1 (nollavesitorniin)	%
390	Sameasuodossäiliön pinta, venttiili 2 (nollavesisyöttö)	%
391	Kirkassuodossäiliön pinta, asetusarvo	%
392	Kirkassuodossäiliön pinta, mittaus	%
393	Kirkassuodossäiliön pinta, ohjaus	%
394	Kirkassuodossäiliön pinta, venttiili 1 (kiekkosuotimille)	%
395	Kirkassuodossäiliön pinta, venttiili 2 (superkirkassuodossäiliöön)	%
396	Kirkassuodossäiliön pinta, pumpun 3 nopeus (kirkastorniin)	%
397	Kemiallisen veden virtaus kirkassuodossäiliöön	l/s
398	Superkirkassuodossäiliön pinta	%
399	Superkirkassuodossäiliön täyttö, asetusarvo	%
400	Superkirkassuodossäiliön täyttö, mittaus	%
401	Superkirkassuodossäiliön täyttö, ohjaus	%
402	Suihkuvesisihdin syöttöpaine, asetusarvo	kPa
403	Suihkuvesisihdin syöttöpaine, mittaus	kPa
404	Suihkuvesisihdin syöttöpaine, ohjaus	%
405	Suihkuvesisihdin syöttöpaine, venttiili	%
406	Suihkuvesisihdin syöttöpaine, pumppu	%
407	Kirkassuodostornin pinta, asetusarvo	%
408	Kirkassuodostornin pinta, mittaus	%
409	Kirkassuodostornin pinta, ohjaus	%
410	Kirkassuodostornin pinta, venttiili 2 (nollavesitorniin)	%
411	Kirkkaan suodoksen paine tornista TMP2:lle, asetusarvo	kPa
412	Kirkkaan suodoksen paine tornista TMP2:lle, mittaus	kPa
413	Kirkkaan suodoksen paine tornista TMP2:lle, ohjaus	%
414	Kirkkaan suodoksen paine tornista PKx:lle, asetusarvo	kPa
415	Kirkkaan suodoksen paine tornista PKx:lle, mittaus	kPa
416	Kirkkaan suodoksen paine tornista PKx:lle, ohjaus	%
417	Kirkkaan suodoksen virtaus kanaaliin, asetusarvo	l/s
418	Kirkkaan suodoksen virtaus kanaaliin, mittaus	l/s
419	Kirkkaan suodoksen virtaus kanaaliin, ohjaus	%
420	Kirkassuodospumppu 1	xxx
421	Kirkassuodospumppu 2	xxx
422	Pudotussuihkupumppu	xxx
423	Nollavesitornin pinta	%
424	Kemiallisen veden virtaus nollavesitornin lämpöpumpulle, asetusarvo	l/s
425	Kemiallisen veden virtaus nollavesitornin lämpöpumpulle, mittaus	l/s
426	Kemiallisen veden virtaus nollavesitornin lämpöpumpulle, ohjaus	%
427	Nollaveden runkolinjan paine, asetusarvo	kPa
428	Nollaveden runkolinjan paine, mittaus	kPa
429	Nollaveden runkolinjan paine, ohjaus	%
430	Nollaveden runkolinjan lämpötila	C
431	Nollaveden pH	pH
432	Nollavesisäiliön pinta, asetusarvo	%
433	Nollavesisäiliön pinta, mittaus	%
434	Nollavesisäiliön pinta, ohjaus	%
435	Nollavesisäiliön pinta, venttiili 1 (nollavesitorniin)	%
436	Nollavesisäiliön pinta, venttiili 2 (nollavesitornista)	%
437	Korkeapaineisen sakeussäätöveden paine, asetusarvo	kPa
438	Korkeapaineisen sakeussäätöveden paine, mittaus	kPa
439	Korkeapaineisen sakeussäätöveden paine, ohjaus	%
440	Matalapaineisen sakeussäätöveden paine, asetusarvo	kPa
441	Matalapaineisen sakeussäätöveden paine, mittaus	kPa
442	Matalapaineisen sakeussäätöveden paine, ohjaus	%
443	Nollavesisäiliön pumppu	xxx
444	Korkeapaineisen sakeussäätöveden pumppu	xxx
445	Matalapaineisen sakeussäätöveden pumppu	xxx
Sekoitus- ja konesäiliö		
446	Sekoitussäiliön pinta, asetusarvo	%
447	Sekoitussäiliön pinta, mittaus	%

448	Sekoitussäiliön pinta, ohjaus	%
449	Alunan virtaus sekoitussäiliöön, asetusarvo	l/min
450	Alunan virtaus sekoitussäiliöön, mittaus	l/min
451	Alunan virtaus sekoitussäiliöön, ohjaus	%
452	Konemassan tuhka, asetusarvo	%
453	Konemassan tuhka, mittaus	%
454	Konemassan tuhka, ohjaus	l/s
455	Täyteaineen virtaus sekoitussäiliöön, asetusarvo	l/s
456	Täyteaineen virtaus sekoitussäiliöön, mittaus	l/s
457	Täyteaineen virtaus sekoitussäiliöön, ohjaus	%
458	Sekoitussäiliön sakeus, asetusarvo	%
459	Sekoitussäiliön sakeus, mittaus	%
460	Sekoitussäiliön sakeus, ohjaus	%
461	Konesäiliön pinta	%
462	Konesäiliön kokonaissakeus	%
463	Konesäiliön tuhkasakeus	%
464	Konemassan sakeus viirakaivoon	%
465	Konemassan virtaus, asetusarvo	l/s
466	Konemassan virtaus, mittaus	l/s
467	Konemassan virtaus, ohjaus	%
468	Konemassan paine	kPa
Lyhytkierto ja perälaatikko		
469	Viirakaivon pinta, asetusarvo	%
470	Viirakaivon pinta, mittaus	%
471	Viirakaivon pinta, ohjaus	%
472	Viirakaivon ylijuoksun pinta, asetusarvo	%
473	Viirakaivon ylijuoksun pinta, mittaus	%
474	Viirakaivon ylijuoksun pinta, ohjaus	%
475	Viirakaivon lämpötila, asetusarvo	C
476	Viirakaivon lämpötila, mittaus	C
477	Viirakaivon lämpötila, ohjaus	%
478	Viiraveden pH 1	pH
479	Viiraveden pH 2	pH
480	Laimean lipeän virtaus viirakaivon lähtöön	ml/s
481	Täyteaineen virtaus viirakaivon lähtöön, asetusarvo	l/s
482	Täyteaineen virtaus viirakaivon lähtöön, mittaus	l/s
483	Täyteaineen virtaus viirakaivon lähtöön, ohjaus	%
484	Ilmanpoistosäiliön pinta, asetusarvo	%
485	Ilmanpoistosäiliön pinta, mittaus	%
486	Ilmanpoistosäiliön pinta, ohjaus	%
487	1. pp sekoituspumpun nopeus	r/min
488	Ilmanpoistosäiliön ylijuoksun pinta	%
489	Ilmanpoistosäiliön lämpötila	C
490	Ilmanpoistosäiliön alipaine	kPa
491	1. pp ilmapitoisuus, asetusarvo	til.%
492	1. pp ilmapitoisuus, mittaus	til.%
493	1. pp ilmapitoisuus, ohjaus	ml/min
494	Liuennut ilma	til.%
495	2. pp syöttö, kuristusventtiili	%
496	3. pp syöttö, kuristusventtiili	%
497	3. pp rejekti, kuristusventtiili	%
498	4. pp syöttö, kuristusventtiili	%
499	4. pp aksepti, kuristusventtiili	%
500	5./6. pp laimennusvesisäiliön pinta, asetusarvo	%
501	5./6. pp laimennusvesisäiliön pinta, mittaus	%
502	5./6. pp laimennusvesisäiliön pinta, ohjaus	%
503	5. pp syöttö, kuristusventtiili	%
504	5. pp aksepti, kuristusventtiili	%
505	6. pp syöttö, kuristusventtiili	%
506	6. pp vastaveden paine, asetusarvo	kPa
507	6. pp vastaveden paine, mittaus	kPa
508	6. pp vastaveden paine, ohjaus	%
509	6. pp vastaveden virtaus	l/s
510	6. pp rejektin virtaus	l/s
511	Rejektisäiliön pinta, asetusarvo	%
512	Rejektisäiliön pinta, mittaus	%
513	Rejektisäiliön pinta, ohjaus	%
514	Rejektin virtaus jäteveden käsittelyyn	l/s
515	Rejektisihdin paine-ero	kPa
516	Rejektisihdin rejektin virtaus, asetusarvo	l/s
517	Rejektisihdin rejektin virtaus, mittaus	l/s
518	Rejektisihdin rejektin virtaus, ohjaus	%
519	Rejekti 5./6. pp laimennussäiliöön, kuristusventtiili, asetusarvo	%
520	Rejekti 5./6. pp laimennussäiliöön, kuristusventtiili, mittaus	%
521	Rejekti 5./6. pp laimennussäiliöön, kuristusventtiili, ohjaus	%
522	Perälaatikon paine, asetusarvo	kPa
523	Perälaatikon paine, mittaus	kPa
524	Perälaatikon paine, ohjaus	%

525	Peränsyöttöpumpun nopeus	r/min
526	Perälaatikon paine KP	kPa
527	Perälaatikon paine HP	kPa
528	Huuliaukko	mm
529	Suihkusuhde	r/min
530	Perälaatikon sivuvirtaus KP	l/s
531	Perälaatikon sivuvirtaus HP	l/s
532	Perälaatikon ohikiertoventtiili	%
533	Perälaatikon lämpötila	C
534	Perälaatikon johtokyky	mS/m
535	Perälaatikon kokonaissakeus	%
536	Perälaatikon tuhkasakeus	%
537	Kokonaisretentio	%
538	Tuhkaretentio	%
539	Perälaatikon tuhkasakeus, asetusarvo	%
540	Perälaatikon tuhkasakeus, mittaus	%
541	Perälaatikon tuhkasakeus, ohjaus	l/s
542	Sisäviiran sakeus, asetusarvo	%
543	Sisäviiran sakeus, mittaus	%
544	Sisäviiran sakeus, ohjaus	%
545	Sisäviiran kokonaissakeus	%
546	Sisäviiran tuhkasakeus	%
547	Ulkoviiran kokonaissakeus	%
548	Ulkoviiran tuhkasakeus	%
549	Retentioaine 1 virtaus, asetusarvo	l/min
550	Retentioaine 1 virtaus, mittaus	l/min
551	Retentioaine 1 virtaus, ohjaus	%
QCS		
552	Neliöpaino, asetusarvo	g/m²
553	Neliöpaino, mittaus	g/m²
554	Neliöpaino, ohjaus	l/s
555	Kuivapaino, asetusarvo	g/m²
556	Kuivapaino, mittaus	g/m²
557	Kuivapaino, ohjaus	l/s
558	Ennakoiva kuivapaino, asetusarvo	g/m²
559	Ennakoiva kuivapaino, mittaus	g/m²
560	Ennakoiva kuivapaino, ohjaus	l/s
561	Kosteus, asetusarvo	%
562	Kosteus, mittaus	%
563	Kosteus, ohjaus	kPa
564	Paperin tuhka, asetusarvo	%
565	Paperin tuhka, mittaus	%
566	Paperin tuhka, ohjaus	l/s
567	Konemassan tuhkaosuus	%
568	Konemassan tuhka, asetusarvo	%
569	Konemassan tuhka, mittaus	%
570	Konemassan tuhka, ohjaus	l/s
571	Perälaatikon tuhka, asetusarvo	%
572	Perälaatikon tuhka, mittaus	%
573	Perälaatikon tuhka, ohjaus	l/s
574	Viiravesisakeus, asetusarvo	%
575	Viiravesisakeus, mittaus	%
576	Viiravesisakeus, ohjaus	l/min
577	Koordinoitu nopeus, asetusarvo	m/min
578	Koordinoitu nopeus, mittaus	m/min
579	Koordinoitu nopeus, ohjaus	m/min
580	Koneen nopeus, asetusarvo	m/min
581	Koneen nopeus, mittaus	m/min
582	Koneen nopeus, ohjaus	m/min
583	8. kuivatusryhmän nopeus	m/min
Kiekkosuotimen RM3		
584	Kiekkosuotimen nollaveden sakeus	%
585	Kiekkosuotimen nollaveden tuhkasakeus	%
586	Suodosmassan tuhkasakeus	%
Pulpperien sekoitinten käyntitiedot		
587	Reunanauhapulpperi	xxx
588	Pituusleikkuripulpperi 2 sekoitin 1	xxx
589	Pituusleikkuripulpperi 2 sekoitin 2	xxx
590	Pituusleikkuripulpperi 1 sekoitin 1	xxx
591	Pituusleikkuripulpperi 1 sekoitin 2	xxx
592	Superkalanteripulpperi 2	xxx
593	Superkalanteripulpperi 1	xxx
594	Konepulpperi sekoitin 1	xxx
595	Konepulpperi sekoitin 2	xxx
596	Puristinpulpperi 2 sekoitin 1	xxx
597	Puristinpulpperi 2 sekoitin 2	xxx
598	Puristinpulpperi 1 sekoitin 1	xxx
599	Puristinpulpperi 1 sekoitin 2	xxx

600	Nokkakyyppi sekoitin 1	xxx
601	Nokkakyyppi sekoitin 2	xxx
602	Hylkyrullapulpperi	xxx
Katkotiedot (jalostetut)		
603	Katko paperikoneella	xxx
604	Katko puristusosalla (jäävä)	xxx
605	Katko kuivatusosalla (jäävä)	xxx
606	Katko rullaimella (jäävä)	xxx
Katkotiedot valokennoilta		
607	Katko rullain	xxx
608	Katko Syl 40	xxx
609	Katko Syl 40 #2	xxx
610	Katko VAC 34	xxx
611	Katko VAC 27	xxx
612	Katko VAC-roll 4	xxx
613	Katko 4. pur. paperinjohtotela	xxx
614	Katko 4. pur.pap.jt. hp	xxx
615	Katko 4. pur.p.j. tela	xxx
Muut signaalit		
616	Paperin neliöpaino (ei kuivamassa) (lajinvaihdon voi päätellä tästä)	g/m^2
617	Rullanvaihto (70s pulssi kun terä lyönyt)	xxx
618	Rullanvaihto (10s pulssi, vaihto tehty käytöille)	xxx
Pumppujen käyntitietoja		
619	Hylkyrullapulpperi pumppu 1	xxx
620	Hylkyrullapulpperi pumppu 2	xxx
621	Reunanauhapulpperi pumppu 1	xxx
622	Reunanauhapulpperi pumppu 2	xxx
623	PL62 pumppu	xxx
624	PL61 pumppu	xxx
625	SK2 pumppu	xxx
626	SK1 pumppu	xxx
627	Konepulpperin pumppu	xxx
628	Puristinpulpperi 2 pumppu	xxx
629	Puristinpulpperi 1 pumppu	xxx
630	Tornin pumppu	xxx