Tampere University of Applied Sciences

Dregs Separation Equipment Selection

Andritz Dregs Separation

Lotta Rahola

BACHELOR'S THESIS
April 2023

Environmental Engineering

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Environmental Engineering

LOTTA RAHOLA
Dregs separation equipment selection
Andritz dregs separation

Bachelor's thesis 27 pages
April 2023

The thesis was commissioned by Andritz Oy and was made for Pulp and Paper White Liquor Plant division. The goal of this thesis was to review centrifuge markets for more optimal dregs separation solutions.

The dregs separation is an important part of recausticization and vital in order to find better possible solutions to replace the current centrifuges that handle the separation. In this study, different machines were investigated and compared to the current ones Andritz is using. There were four different machines that offered possible solutions. A meeting was held regarding each possible replacement machine. Possible replacement solutions were discussed in these meetings, and a specialist of the machine in question was present in the meeting

All the specialists received data from Andritz’s needs and what was expected from the machines. Based on the data, the specialists gave their opinions on whether their machines would work with the process or not. Machines A, B, C and D turned out not to be qualified for this process due to different particle size requirements and not being able to work well with dregs.

Even though machine D did not work well for this process, the specialist of machine D offered another kind of solution to make the process more effective and financially sustainable. The specialist recommended machine E to be used as a thickener before the solution enters to the centrifuge. Machine E could be more cost-effective solution in alkali recovery without increasing polymer consumption. Under certain process conditions machine E could improve existing centrifuge process performance and in new plant possibly replace the other centrifuge.

Calculations were made to see if the machine E could make any difference and different possible scenarios were considered. The calculations showed some good results and a deeper study of the possibility to use machine E as a part of the process could potentially be reasonable. Usage of machine E and automating the process with online measurements could potentially make the process more efficient while reducing the losses.

---

dregs separation, centrifuge, recausticization

CONTENTS

1 INTRODUCTION

The pulp and paper industry is one of the biggest industries in the world. (Paper Industry Growth… 2021) In 2021 the total consumption of paper and paperboard globally was 408 million tons. (Paper consumption worldwide… 2023) One of the main providers in the pulp and paper industry is Andritz. It offers plants, equipment and systems to the pulp and paper industry. They have built hundreds of pulp and paper mills over the years, and they have access to the newest technology. (Andritz services…n.d.)

The process of making pulp has many steps and it starts from the wood handling. The wood is processed – peeled, washed, wood chips are made and after that it is processed into pulp by various processes. When the wood chips are ready, the pulp can be produced either chemically or mechanically. In chemical pulp production, the purpose of the boiling is to use chemicals and heat to remove binding to such an extent that the wood chips are easily fibered and become cellulose. (Sellun valmistus 2023) It is called a sulphate method when sodium hydroxide is used on the boiling part and sulfite method when acid is used instead of sodium hydroxide. (Rullifank et al. 2020)

The sulphate method uses white liquor as a cooking chemical, which contains approximately 9% of sodium hydroxide ($NaOH$), 3% of sodium sulfide (Na_2S) and 1% of sodium sulfate (Na_2SO_4). Boiling takes place above $pH\,12$ and at a temperature of $160 - 180℃$. The length of the process is from 30 minutes to 3 hours, depending on the used temperature, as well as the desired final concentration of lignin. (Recausticizing n.d.)

The recausticization is part of the factory's lye cycle and inside of the recausticization happens the lime cycle. Lime is a circulating auxiliary chemical used to convert green liquor from the recovery boiler into white liquor for cooking. The active chemicals in sulfate cook are sodium hydroxide and sodium sulfide. The process where sodium carbonate is converted into sodium hydroxide is called recausticizing. The main chemicals in green liquor are Na_2CO_3 and Na_2S . In addition to these, it contains some other sodium compounds, e.g., $NaOH$,

Na_2SO_4, $Na_2S_2O_3$ and $NaCl$. The $NaOH$ comes from the weak white liquor used to dilute the green liquor. There are also some non-soluble compounds in green liquor. These include soot from incomplete burning, metal oxides caused by corrosion, silicates due to wearing of linings and substances brought in by impurities from replacement chemicals or wood. The non-soluble matter accounts for approx. 0.03...0.1% of the amount of green liquor. The insoluble matter is called green liquor dregs. It is removed from the green liquor through filtration or clarification. After that, the green liquor is ready for recausticizing. (Recausticizing n.d.)

The purpose of green liquor treatment is to remove the dregs from the green liquor coming from the recovery boiler and to adjust the alkali content and temperature to be suitable. This improves the recausticizing and lime kiln performance. Before the recausticizing comes clarifier or filtering. In the green liquor filter, the raw green liquor flows downward alongside the filtering elements. Part of the green liquor penetrates through the filter cloth. The dregs cannot go through the cloth because of the downward flow is much higher than the flow through the filter elements. The pressure difference is the driving force for the liquor flow to go through the cloth pores into the filtrate space. The green liquor clarifier is designed to have a clarifier section and a storage section. In the clarification part, the dregs are separated from the green liquor, and it settles to the bottom of the clarifying agent. The settling of the dregs can be enhanced by adding polymer to the mixture. The dregs are pumped to the dregs filter for washing and increasing the dry matter content. The dry and clean dregs are removed from the process. Dregs filter can also be used for this process. The dregs filter works in stages. The steps included are making of the new precoat, filtration and the movement of doctor blade to scrape off the clogged lime mud layer from the surface of the precoat. Once the innermost limit is reached, the precoat is replaced and the filtration can start again. (Recausticizing n.d.)

For this green liquor handling process Andritz uses decanter centrifuge, D-type Decanter. It separates liquid and solid phases by centrifugal force. Liquid phase is returned into chemical circulation. To achieve high alkali recovery rate, separated solids are mixed with hot water and separated again using same or second centrifuge. Major benefit of centrifuge is that no lime mud pre-coat is needed – which reduces solid waste output by about 50% compared to dregs filter. (Process training LimeFree 2022) While these two phased processes are done efficiently with two centrifuges, requirements in process optimization are different between those phases. In addition, dilution as a washing method is not as effective as dregs washing could be. The goal of this thesis was to find out if there were better solutions for Andritz in this area. In more detail, the aim was to find out if there were dregs separating equipment that could save more money, take less space, would need less water, where the residual alkali percentage would be better, and it could give a drier product out. Emphasizing good alkali recovery and great dregs dry solids content is important. (Kuusrainen 2023)

To find out the best solution for Andritz, different centrifuges and other devices that could help with the process have been compared. This was done by interviewing professionals of different companies that offer these types of equipment, comparing these options with the current machines Andritz is using and keeping in mind the wanted results. From these options, it was narrowed down the best solutions for Andritz to use in their process of separating the dregs in white liquor plants.

2 ANDRITZ OY

2.1 Andritz in Finland

Andritz Oy is a leading global supplier offering services, systems and equipment for the pulp and paper industry. This includes wood processing, fiber processing, chemical recovery, and stock preparation. They also offer biomass boilers and gasification plants for energy production. Andritz has over 1600 employees in Finland (including Andritz Hydro Oy). The headquarters are in Helsinki, but they have offices and workshops in Kerava, Kotka, Lahti, Lappeenranta, Oulu, Savonlinna, Tampere, Vantaa and Varkaus. Andritz Oy is part of a global technology group Andritz. (Andritz in Finland… n.d.)

2.2 Pulp and Paper

Andritz Pulp and Paper is their own division that focuses only on pulp and paper production. It is their leading business area. Other business areas are metals, hydro and separation. Andritz has a complete portfolio of systems for pulp and paper production, starting from the woodyard to the finished product. This includes

- Processing of logs, annual fibers and biomass
- Production of chemical, mechanical and recycled fiber pulps
- Chemical recovery
- Power generation from traditional and alternative fuels
- Stock preparation, including denking
- Machine approach systems
- Machines for tissue, board, and paper production
- Finishing/calendaring/coating
- Handling of rejective materials and sludges (Pulp and Paper 2022)

2.3 White Liquor Plant

White liquor plant (WLP) is part of the pulp mill production. An important part of the chemical cycle is the production of white liquor in pulp production, as the hot molten green liquor from the recovery boiler is utilised in the production of white liquor and this white liquor is used in pulp cooking. Andritz Paper and Pulp offers white liquor plants to pulp mills. (White Liquor Plant, n.d.) Figure 1 shows the pulp line and chemical recovery by Andritz. Numbers eight (Recausticizing) and nine (Lime kiln) in the figure 1 form the white liquor plant. Andritz is currently the leading white liquor plant supplier by having an 80% market share (Andritz Strategy Plan n.d.)

The main challenges white liquor plants might face circle around efficient conversion of green liquor to white liquor, the purity of cooking liquors and overall efficiency and reduction of dregs getting in landfill. Andritz offers full support as well optimized processes as productivity of white liquor plant from recausticizing plant to lime kiln. Their services range from single replacement parts to Overall Production Efficiency (OPE) agreements for a specific process or an entire white liquor plant. (Andritz services… n.d.)

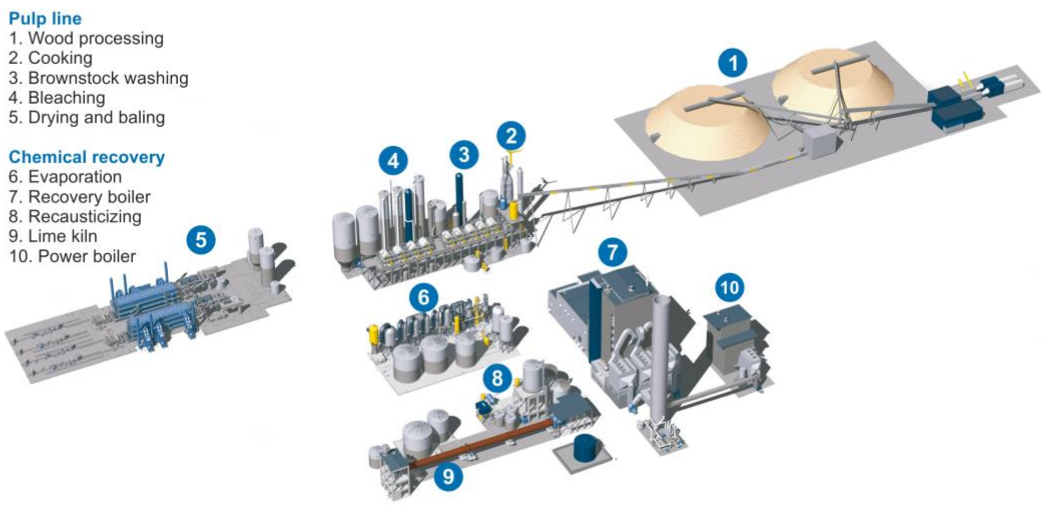

Figure 1 Pulp line and Chemical recovery (Andritz 2022)

3 THEORY OF CENTRIFUGATION

Centrifugation is a mechanical process where centrifugal forces are used to separate particles from a solution depending on their size, shape, density, medium viscosity, and rotor speed. The idea behind this technique is to get the bigger and denser particles of the mixture to migrate away from the axis and at the same time the less dense particles and components of the mixture are migrating towards the axis. (Centrifugation and centrifuges n.d.) When there is a need to separate a none-miscible two or three phase mixture (solid & liquid OR liquid & liquid OR solid & liquid & liquid) this can be accomplished using centrifugation due to the volume mass difference between these phases. There is a correlation between the density and size of the particle when the particle separates from a heterogeneous mixture, while the only force applied is gravity. The bigger the particle's size and density is, the faster it separates from the mixture. The separation can be speeded up by applying a larger effective gravitational force to the mixture. (Centrifugation basics n.d.)

Gravity force formula: $F = mg$

Centrifuge force formula: $F = m\omega^2 R$

where

m is the mass (kg)

R is the radius (m)

ω is the rate of rotation (rad/s)

g is the gravity acceleration $(9{,}81\ m/s^2)$.

$$\frac{F(m\omega^2 R)}{F(mg)} = \frac{\omega^2 R}{g}$$

Static decantation is $G = 1\ (without\ units)$

Centrifuge decantation is $G = \frac{D \cdot N^2}{1800}\ (without\ units)$

where

D is diameter (m) and

N is rotation speed (rpm)

Decanter: *3000 G*

Disc Centrifuge Separator: *15 000 G*

Ultra-Centrifuge: *300 000 G*

Stokes' law

$$v = \frac{2}{9}\frac{(\rho_p - \rho_f)}{\mu} g R^2$$

where

g is the gravitational acceleration ($9{,}81\ m/s^2$)

R is the radius of the spherical particle (m)

ρ_p is the mass density of the particles (kg/m^3)

ρ_f is the mass density of the fluid (kg/m^3)

μ is the dynamic viscosity ($kg/m \cdot s$) (D-type Centrifuge training 2022)

This technique has been found effective on dregs separation in chemical recovery and therefore Andritz uses equipment with centrifugal forces as a part of their process. Figure 2 showcases the settling velocity and how the decanter works with centrifugal forces.

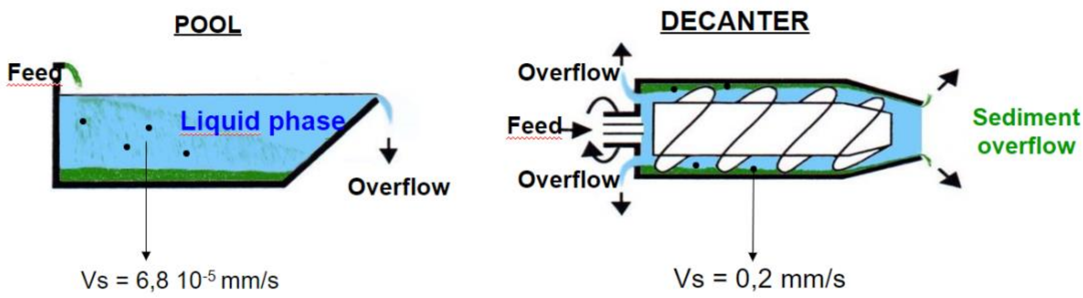

Figure 2 Settling velocity showcased in a picture (Andritz 2022)

4 THE PROCESS

4.1 Process Overview

After the concentrated dregs, have come out from the LimeGreen Filter, they enter the dregs tank. From there the dregs travel to two centrifuges that are used to separate the dregs from green liquor. The green liquor is returned to the process and the washed dregs are discharged from the process. The centrifuge operates close to atmospheric pressure and inside the centrifuge the dregs are separated by centrifugal force. (Process training LimeFree 2022) The placement of the centrifuges in dregs separation process pictured in figure 3.

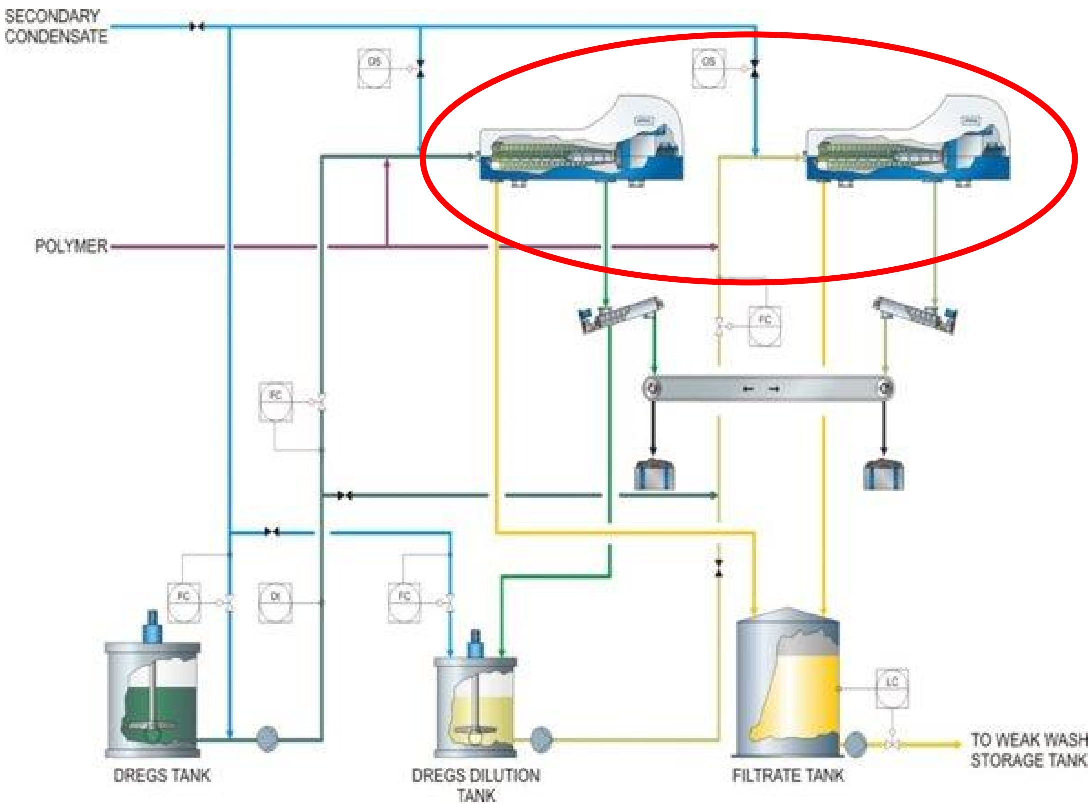

Figure 3 Dregs separation process pictured with 2 D-type decanter centrifuges (Andritz 2022)

4.1.1 Process Overview, Polymer

Andritz adds polymer to the centrifuge feed in order to maximize the dry solids in the discharged dry solids cake and to minimize the carryover of dregs into the centrate. The polymer flocculates dregs particles to form conglomerates. These are easier to separate from the liquor than the small individual dreg particles. The polymer dosage depends on the centrate's suspended solids target and from the dregs moisture and transportability target. (Process training LimeFree 2022)

Polymers are natural or synthetic substances that are composed to very large molecules. They are multiples or simpler chemical units. Polymers make up many of the materials in living organisms and cellulose is one of those materials. (Britannica 2022) Figures 4 and 5 show how the added polymer helps the dregs to separate easily from the liquid before and after mixing.

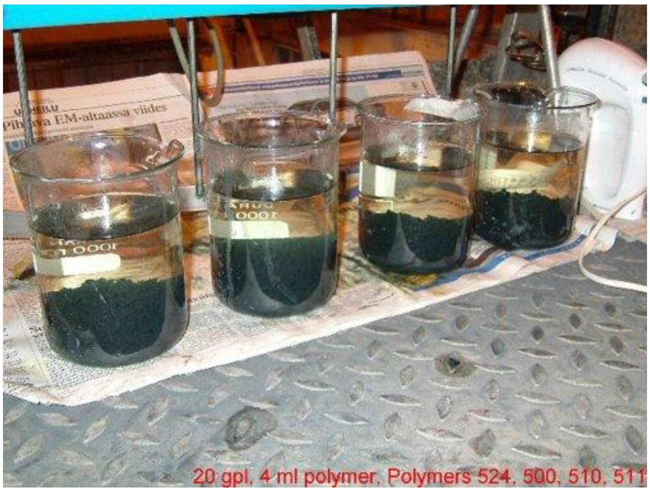

Figure 4 Different polymers added to dregs mixture before mixing (Andritz 2022)

Figure 5 Different polymers added to dregs mixture after mixing (Andritz 2022)

The flow setpoint is calculated in the distributed control system (DCS) based on the following information:

- Dregs concentration
    - Entered by the operator based on lab tests (0-100 g/l).

    - Different for each stage
- Dregs flow rate
    - Measured by each flow meter
- Polymer dosage
    - Set by the operator for each stage (0-10 kg of polymer/ton of dregs)

These forms together the first stage, which includes unwashed dregs from the dregs tank and the second stage, which includes the prewashed dregs from the dregs dilution tank. Polymer concentrations are the same for both stages. (Process training LimeFree 2022)

4.1.2 Process Overview, Dregs Tank

The dregs tank is an intermediate storage tank that participates in four different activities of the dregs handling system. It receives dregs from the LimeGreen Filter during the discharging cycles. It also provides dregs for the thickening cycles in the LimeGreen Filter and receives the pressure relief flow from the LimeGreen Filter. What makes it an essential part for the dregs separation and centrifuges, is that it feeds the tanks to the LimeFree D-type decanter centrifuges. (Process training LimeFree 2022) Dregs tank pictured in figure 6.

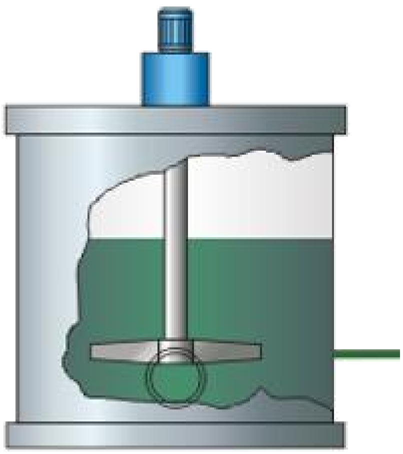

Figure 6 Dregs tank (Andritz 2022)

4.2 The whole process

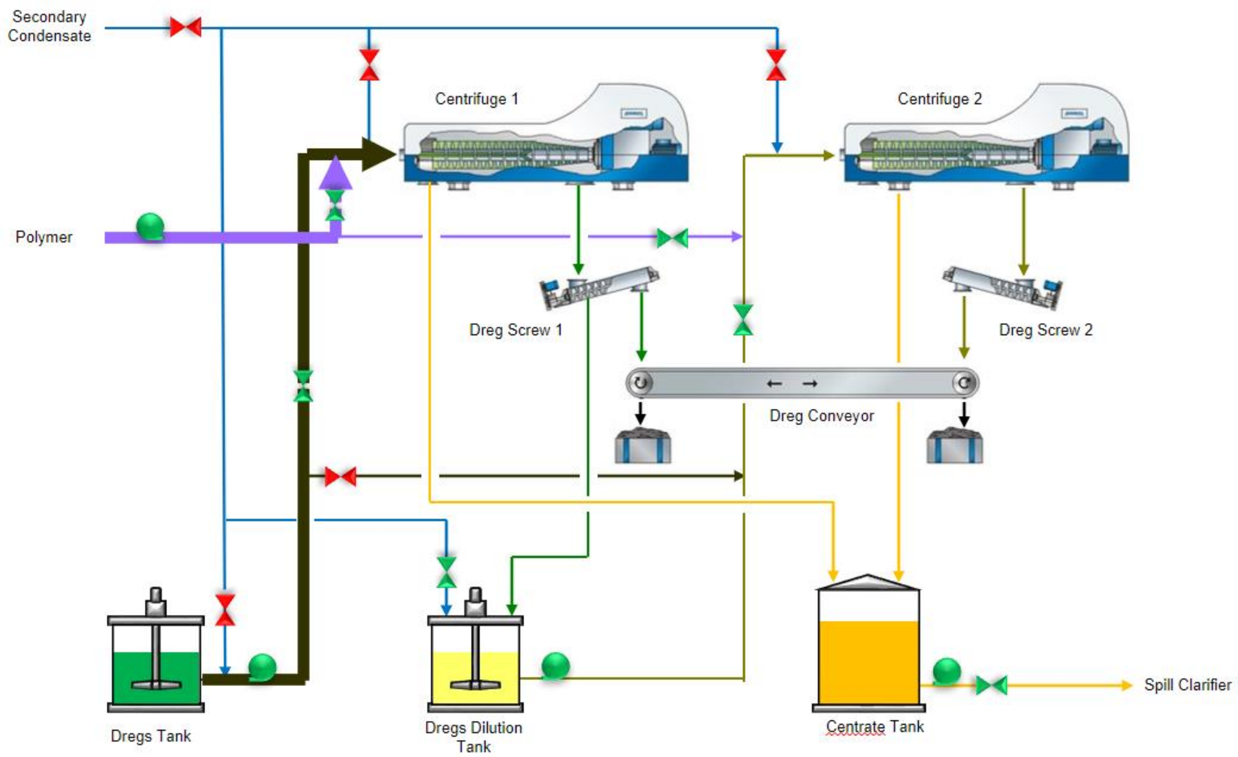

Figure 7 The Dregs Separation Process (Andritz 2022)

Figure 7 shows the steps of the dregs separation process. First the dregs from the dregs tank are pumped to Centrifuge 1. The system works as a two-stage continuous process. Then the polymer is added to the dregs before they go to the Centrifuge. It makes solids flocculate and makes the separation process easier. The dregs are separated from the liquid by centrifugal forces. After the separation the dregs fall from Centrifuge 1 to the dregs Screw 1 and are transported to the Dregs Dilution Tank. In the Dilution Tank the dregs are mixed and diluted with secondary condensate. Meanwhile the filtrate from Centrifuge 1 flows to the Centrate Tank. Polymer is added to the diluted dregs before they enter to the Centrifuge 2. In the second stage the dregs are pumped from the Dregs Dilution Tank to the Centrifuge 2 where the separated dregs fall to the Dregs Screw 2 and are transported to the Dregs Conveyor. The Conveyor transfers the dregs to the container and discharges them away from the process.

The filtrate from Centrifuge 2 flows to the Centrate tank and clean liquid is pumped to the Weak wash tank (Process Training LimeFree 2022) From there it continues its journey to the lime slaking. (Recaustizing n.d.)

5 CURRENT SITUATION

Andritz is currently using two D-type decanter centrifuges for their dregs' separation process. This method washes the alkali by diluting. The problem comes from the fact that there are two centrifuges needed, and one of the centrifuges could possibly be removed or exchanged for a different type of machine in order to make the process more effective. If the washing of the cake could be carried out inside the centrifuge, as it is done in some other types of models, it would be beneficial. The D-type decanter centrifuges are expensive and take a lot of space from the layout. It would be ideal to find a machine that integrates dregs washing, making the other centrifuge unnecessary. This could reduce carbon footprint, water consumption, and capital investment. (Process Training LimeFree 2022) Figures 8 and 9 show the D-type of decanter centrifuge Andritz is currently using.

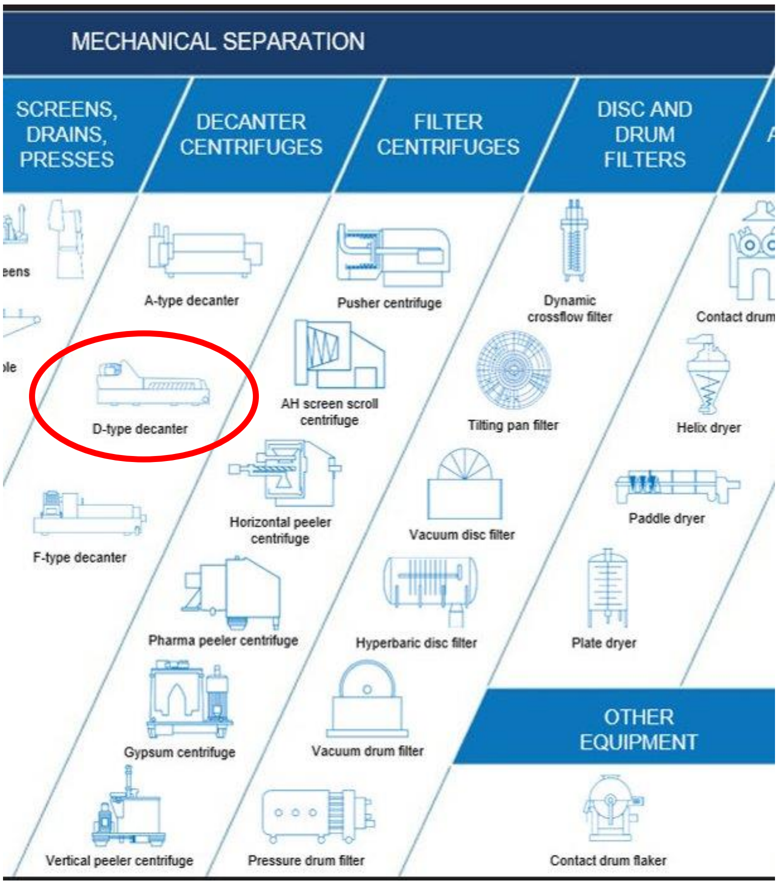

Figure 8 Decanter Centrifuges and other equipment from Andritz (Andritz 2023)

Figure 9 D-type decanter (Andritz n.d.)

Below are some details of what is needed from the machines:

Sludge feed should produce

- Solids particle size 50-2000 μm
- Dregs density is 1200 kg/m^3 – 2000 kg/m^3
- Capacity 10-40 tons per day
- Temperature 80-95 ℃
- Liquid density 1140 kg/m^3
- 25g/l-60 g/l Suspended Solids

The output should be optimized for

- residual alkali in dregs (washing efficiency)
- dry solids in dregs (drying efficiency)

Current machines are bringing good results but development in the field could be an opportunity to improve the process further. In case the compared machines cannot meet the current standards, then the current equipment Andritz is using is the best technology available.

6 MACHINE A

For the machine A, a meeting was held with a specialist explaining about the possible solution for Andritz with dregs handling. The meeting was held on the 26th of January in 2023. The machine A was seen as a good option for this kind of process based on the similarities to current centrifuges. Machine A offered a good accessibility, it did not need pre-thickening and it washed the product at the same time. With this option, only one machine was able to do the same process where Andritz currently needed two machines. It also operates automatically and continuously. (Kuusrainen 2023)

The person who was specialized in machine A received a data sheet beforehand which included all the requirements Andritz needs from the machine A to be able to produce and process (mentioned above on the chapter 4). On the meeting the specialist suggested that the best suitable centrifuge for this type of process would be the current decanter. This is due to the particle size and capacity requirements. It would make less sense to use any other type of continuous centrifuge. The machine A cannot meet the solids particle size that Andritz is looking for this process. The solids particle size is too small for cake washing and particle recovery would not be high enough (less than 30%). (Lopez 2023)

As a result of this meeting, we found out that the current machines Andritz is using are better than machine A. The current centrifuges Andritz is using now are decanter centrifuges. like the machine A specialist recommended. Based on this it does not make sense to replace the current centrifuges to machine A and no further research was needed.

7 MACHINE B

Machine B was considered to possibly be better than the current two centrifuges and this way to be suitable for this type of process. (Kuusrainen 2023) Machine B offered great energy savings because of its design and its quick assembly or disassembly of the compact spindle drive resulting in reduced costs of service and maintenance. It can have high solids load in the feed and has high separation efficiency and excellent clarification. The particle size range for the machine B was wide and close to what Andritz needed. (Kuusrainen 2023)

The meeting regarding machine B took place on the 15th of February in 2023. In the meeting, there was a person who was specialized in machine B and had received some data of Andritz's needs for dregs handling. The requirements for machine B are the same that they were for machine A.

The specialist concluded that the machine B does not work as well with dregs handling as the current centrifuges do. This can be said without any further testing. The specialist is familiar with the process, and this has been tested in the past and it did not work out well. The angle of the exit in the machine B is too steep hence it does not work well together with dregs. The material should be much softer or otherwise it just gets clogged and the whole machine stops working. He recommended to keep using the current centrifuges because the machine B cannot meet up with the requirements Andritz requires. (Eierkaufer 2023)

8 MACHINE C

The machine C was considered to replace the current centrifuges because of its wide particle size range. Even though it did not offer dregs washing it was still a good alternative because it offered also reduced costs of maintenance.

The machine C's shape and design became a problem, like the machine B's shape. The machine C has a unique design, and therefore it does not work well with dregs. It has been designed for different kind of substances. The solid outlet would not have been solid enough and it would have been too wet compared to the desired result. Because of the design the capacity of this machine was also not great. It did not meet the required 10 to 40 tons of sludge per day. (Eierkaufer 2023)

This machine requires pre-filtering for large solid particles. Otherwise, the particle size is too large and cannot get through the filtering. This requires an extra step to the process, and it costs more money and more effort so it would not be a good alternative for Andritz.

The meeting regarding the machine C took place on the 15th of February in 2023. In the meeting there was a person who was specialized in machine C and had received some data from Andritz and its needs for dregs handling. The requirements for machine C are the same as they were for machines A and B.

9 MACHINES D and E

The meeting about machine D was held on the 1st of February in 2023 with a specialist who was familiar with machine D. The information of Andritz's requirements was sent beforehand to the specialist.

On the meeting the specialist said that the current centrifuge that is handling the dregs is better for Andritz's needs compared to what machine D could offer. The machine D cannot go as low with the solids particle sizes as needed and the separation would not be as effective. However, the specialist came up with different solution for the "problem". There are different types of thickeners (machine E) that could improve the overall efficiency of the plant. The machine E thickens the dregs with low additional polymer and can increase dry solids which in turn allows higher capacity from centrifuges. Polymer is costly to use but unavoidable in dregs thickening. With this type of machine, the polymer consumption could be minimized and would be better for the economy. (Evenson 2023)

The machine E is over two times cheaper than current centrifuges. The capacity range is wide and can be customized by Andritz's needs. In theory one Centrifuge can possibly be replaced with two machine E's. The thickeners (machine E) can be placed on top of each other. (Evenson 2023)

10 DISCUSSION

The results from the meetings with different specialists were ideal for Andritz. It proved that Andritz has one of the best technologies in use and optimal machines for their dregs handling. The meeting with machine D specialist gave some new ideas that could possibly save money and make the process more effective this way.

The meetings with the specialists provided enough information and further testing was not necessary. The specialists got the needed information and data of what is needed and expected from the process and from the machines. It gave them enough background to get familiar with the needs and give their opinions of what could be done. All of them were familiar with Andritz beforehand and the process was familiar for them. Some of the specialists had already tested their machines with Andritz and based on previous experiments the results turned out not to be ideal for the dregs handling process.

Table 1 shows that when the other machines were compared to the one Andritz is currently using (D-type centrifuge decanter) machine B was close to the current centrifuge or even better in some points. The particle size range was wide, and the solid outlet larger than the current one's but because of its design it was not a good fit. As it became apparent the exit angle of machine B is too steep and it does not work well with dregs. This had been found from previous experiments. Machine A had almost everything that was needed but because the particle size range was not wide enough and it did not go as low as was needed, it would not work well with the concentration Andritz is using in their process. The dregs washing is something Andritz is missing from their current centrifuge and machine A offered this. That is why it was a great alternative. The same reason Andritz was interested about machine D was the dregs washing opportunity. This turned out not to be working for this process because of the small particle size range. The size range did not go as low as needed. Machine C offered great range of particle sizes but the volume and solid concentrations in feed and solid outlets were too small. It would not have been effective to use machine C for this process.

The current D-type Centrifuge Decanter is still the best choice for Andritz after comparing the machines together.

	D-type centrifuge decanter	Machine A	Machine B	Machine C	Machine D
Solid concentration in feed	$15-100\ g/l$	$0-100\ g/l$	$10-100\ g/l$	$2-15\ g/l$	$15-100\ g/l$
Particle size	$50-2000\ \mu m$	$150-2000\ \mu m$	$2-1200\ \mu m$	$0{,}7-1000\ \mu m$	$150-2000\ \mu m$
Solid outlet	$2{,}5\ t/h$	$5\ t/h$	$3\ t/h$	$1{,}6\ t/h$	NA
Solid in centrate	$0-0{,}5\ g/l$	$0-5\ g/l$	$0-0{,}5\ g/l$	$0-0{,}1\ g/l$	$0-5\ g/l$
Moisture in solid outlet	$30-60\ \%$	$0{,}5-50\ \%$	$25-50\ \%$	$5-20\ \%$	$0{,}5-50\ \%$
Dregs washing	NA	Yes	NA	NA	Yes

Table 1 Comparison of different Centrifuge models. The numbers are assumptions.

After having the meeting with machine D's specialist, it came clear that Andritz should study more of the possibilities with the alternative solution including machine E. As said before, polymers are costly to use but necessary in dregs handling. If the usage of machine E can make the dregs thicker with lower use of polymer this could have a positive financial effect. Replacing one centrifuge with two machine E's could have a positive outcome not only financially but productivity wise too. If one thickener (=machine E) is over two times cheaper than one centrifuge and two of them are needed to replace a one centrifuge to get effective results, it still becomes cheaper to invest in two machine E's and one Centrifuge than two Centrifuges and not using thickeners.

Table 2 shows results from calculations that were made with Andritz's own centrifuge calculation tool. The GFL (Green Filter Liquor) Base is the normal situation (all these scenarios were calculated with the use of Green Liquor Filter and not with Clarifier) that is on use already. GLF + Thickener + High Capacity is a scenario where one thickener is added to the process and the capacity has been brought up by 40% (=high capacity). GLF and replacing CF1 (Centrifuge) means that in this scenario two thickeners are added, and they have been replacing one of the Centrifuges.

	Unit	GLF Base	GLF+Thickener+High Capacity	GLF and replacing CF1
Feed consentration	g/l	25	25	25
Diluted feed consentratioin	g/l	25/25	18/50/50	15/15/25
Alkali loss (without 2% margin)	%	1,52	1,66	1,48
Dilution flow per ton of dry dregs	l/kg	37,9	39	103,4
Output moisture	%	30	30	30
Alkali in centrate	g/l	68	50	12,6
Centrate solids	g/l	0,35	1,35	2,175
Capacity		100 %	140 %	100 %
		1,40 %	5,40 %	8,70 %
GLF		**X**	**X**	**X**
Clarifier				
Thickener 1			**X**	**X**
Thickener 2				**X**
CF 1		**X**	**X**	
CF 2		**X**	**X**	**X**

Table 2 Estimation of productiveness with and without thickeners.

The calculations show that adding one thickener to the process and increasing capacity, the numbers are good. The alkali loss stays almost the same as in the “normal” process. It is important to keep the number low on alkali loss. The usage of water (dilution flow per ton of dry dregs) does not increase much, only 1,1 litres and compared that the capacity has risen in this scenario by 40% it is good. The carry over (percentage under capacity) has increased quite a lot and it is added straight to the green liquor treatment process. So, the number for this should stay as low as possible. In this case because of the possibility to have a greater capacity with one thickener added to the process and still having the usage of water quite low and not increasing the alkali loss, this could be a great potential add on to the process, even though the carryover has risen a bit.

GFL and replacing one CF1 means that Green Liquor Filter and two thickeners have been used to replace one Centrifuge. With this combination the alkali loss decreased few percentages from the base case and gave positive results. The amount of needed washing water grew over twice as large as compared to the two other options. The carry over percentage also increased even more from the GLF + Thickener + high-capacity combination. For this the capacity is kept normal.

Based on these calculations good results were received and especially adding one thickener for high-capacity process would probably be a good investment. Continuing from this Andritz should study this option more and find out which type of thickener (machine E) would work best for this sort of process. Doing more calculations would give more accurate results and calculating other possible combinations to find out the best scenarios where the thickeners could be added to get better results.

Getting to know the process more, it became apparent that feed solid concentration is an important and highly variable process control value. Currently it is followed by laboratory measurements and replacing it with online measurement would improve control accuracy. With accurate measurements plant output could be more constant and savings could be done in polymer consumptions. There are different types of measurements in the market, but further study is needed to determine their usability in this process. Combining machine E and automating the process with online measurements could potentially be a solution for making the process as efficient as possible with minimal losses.

REFERENCES

Andritz in Finland: Forerunner of Innovative Technologies. N.d. Andritz Oy. Read on 20.2.2023 ANDRITZ in Finland

Andritz Services for White Liquor Plants. N.d. Andritz Oy. Read on 2.2.2023 White liquor plant services (andritz.com)

Andritz Strategy Plan. N.d. Andritz Oy. Unpublished. In the possession of the author of the thesis.

Centrifugation and Centrifuges. N.d. Lenntech. Read on 13.2.2023 Centrifugation Lenntech

Centrifugation Basics. N.d. Merck. Read on 13.2.2023 Centrifugation Basics (sigmaaldrich.com)

D-type Centrifuge Training. 2022. Andritz Oy. Unpublished. In the possession of the author of the thesis.

Eierkaufer, G (2023) Conversations in the meeting. February 2023

Evenson, D (2023) Conversations in the meeting. February 2023

Kuusrainen, T (2023) Conversations in the meeting. January 2023

Lopez, D (2023) Conversations in the meeting. January 2023

Paper Consumption Worldwide from 2021 to 2023. 2023. Statista. Read on 9.2.2023 Paper and paperboard demand globally 2021-2032 | Statista

Paper Industry Growth, Development & Location Factors – UPSC. 2021. Lotus Arise. Read on 9.2.2023 Paper Industry Growth, Development & Location Factors - UPSC (lotusarise.com)

Process Training LimeFree. 2022. Andritz Oy. Unpublished. In the possession of the author of the thesis.

Pulp and Paper. N.d. Andritz Oy. Unpublished. In the possession of the author of the thesis.

Recaustizing – General. n.d. KnowPulp. Version 21.0. Read on 7.2.2023 KnowPulp - Recausticizing - general

Rullifank, K F, M E Roefinal, M Kostanti, L Sartika, and Evelyn. 2020. Pulp and Paper Industry: An Overview on Pulping Technologies, Factors, and Challenges. IOP Conference Series: Materials Science and Engineering 845 (1): 012005. https://doi.org/10.1088/1757-899X/845/1/012005.

Sellun Valmistus. 2023. Metsä. Read on 20.2.2023 Sellun tuotanto | Metsä Fibre (metsagroup.com)

The Editors Encyclopedia. “Polymer”. 2022. Encyclopedia Britannica. Britannica. Read on 24.2.2023 Polymer | Description, Examples, Types, Material, Uses, & Facts | Britannica

White Liquor Plant. N.d. Andritz Oy. Unpublished. In the possession of the author of the thesis.