Diploma thesis

High Performance and Cost Efficient Chip-Washing Concepts for Pulp and Paper Industries

Submitted by

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In cooperation with

Andritz AG

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Abstract

One of the first steps in a mechanical pulping process is to wash the wooden chips and by today, several chip washing concepts are in use. As the chip washing unit cannot be seen as a main part of the refining process, searching new technologies for chip washer concepts played a minor role in further developments in the past.

This work gives an insight in the mechanical pulping market in general, where the different market shares of equipment suppliers are worked out, to show who can be seen as big player on the market and to demonstrate whether there is a possibility to raise the singular market share. Based on the existing data, the most commonly used chip washer size has been investigated. Furthermore, a technological analysis of the historical and common chip washing concepts was conducted and the different concepts were compared. The question that needed to be clarified was whether the subordinate role of the chip washer in the process was the only reason why there were no fundamental further or new developments. The main goals of this work are to show the strengths and weaknesses of the concepts in use and to develop one new concept out of three proposals. The development of the new concept also contains a 3-D model and a cost estimate for this concept. There should be the possibility to assemble this new concept in all existing units.

Kurzfassung

Einer der ersten Schritte in einem Holzstoffprozess ist die Waschung der Holzhackschnitzel, wofür heutzutage einige Waschkonzepte in Verwendung sind. Nachdem der Waschprozess nicht als einer der Hauptschritte in einem Holzstoffprozess gesehen werden kann, spielten technologische Weiterentwicklungen dieses Prozessschrittes in der Vergangenheit eine relativ unwesentliche Rolle.

Diese Arbeit gibt einen groben Einblick über die Marktverhältnisse des Holzstoffmarktes, wobei die einzelnen Marktanteile der Zulieferer für diesen Industriezweig herausgearbeitet werden, um diejenigen Unternehmen festzustellen, welche derzeit die größten Marktanteile innehaben. Auch soll hierbei festgestellt werden, ob die Möglichkeit besteht, einzelne Marktanteile durch neue Technologien zu vergrößern. Aufgrund vorliegender Daten wurde die am meisten verbaute Hackschnitzelwäschergröße festgestellt. Weiterhin wurden Technologieanalysen über vergangene und heutzutage verwendete Wäscherkonzepte durchgeführt und diese miteinander verglichen. Eine der zu klärenden Fragen war, ob die untergeordnete Rolle, welche die Wäsche in dem Gesamtprozess darstellt der einzige Grund für keine Neuentwicklungen bis dato war. Den Kern dieser Arbeit bilden die Feststellung der Stärken und Schwächen vorhandener Konzepte und eine Entwicklung von neuen Wäschekonzepten. Hierfür sollen zumindest drei Konzeptvorschläge entwickelt werden, wobei das für eine potentielle Realisierung in Frage kommende einer Detailbetrachtung unterzogen wird. Die Erstellung eines 3D Modells dieses neuen Konzeptes ist auch Teil dieser Arbeit mit der Möglichkeit es in bestehende Anlagen einzubauen.

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1 Introduction

Today, mechanical pulping processes play a very important role compared to other technologies in the pulp and paper industry. There are several mechanical pulping processes in use with different methodologies, which are listed in the following table:

Existing mechanical Pulp Nomenclature and Pulping Methodology			
SGW	Stone Groundwood; atmospheric grinding	**CRMP**	Chemi-Refiner-Mechanical Pulp; atmospheric (low-temperature) chemical treatment; atmospheric refining
PGW	Pressurized Groundwood; grinding at temperature higher than (>) 100 °C	**CTMP**	Chemi-Thermo-Mechanical Pulp; presteaming with chemical treatment at >100 °C; first-stage refining at >100 °C; second-stage atmospheric refining
RMP	Refiner Mechanical Pulp; atmospheric refining with no pretreatment	**TCMP**	Thermo-Chemi-Mechanical Pulp; presteaming with chemical treatment at >100 °C; atmospheric refining
TRMP	Thermo-Refiner Mechanical Pulp; presteaming of chips at >100 °C; atmospheric refining	**TMCP**	Thermo-Mechanical-Chemi Pulp (or OPCO Pulp); first-stage refining at >100 °C; atmospheric chemical treatment; second-stage atmospheric refining
PRMP	Pressure Refined Mechanical Pulp; no presteaming; first-stage refining at >100 °C; second-stage refining at >100 °C	**LFCMP**	Long Fiber Chemi-Mechanical Pulp (or) chemically Treated Long Fiber; long fiber is separated from mechanical pulp; it is then chemically treated and refined
TMP	Thermo-Mechanical Pulp; presteaming of chips at >100 °C; first-stage refining at >100 °C; second-stage atmospheric refining or pressurized refining	**RTS Single Stage**	Low (R) residence time at a (T) temperature exceeding the glass transition temperature of lignin and elevated disc (S) speed in the primary pressurized refiner; Only one mainline refiner. A reject refiner after screening.
PPTMP	Pressure/Pressure Thermo-Mechanical Pulp; presteaming of chips at >100 °C; first-stage refining at >100 °C; second-stage refining at >100 °C	**RTS²**	Two stage refining. Both stages are high speed (2300 rpm), the second stage is the same like the first stage.
		Thermopulp	Two stages at normal speed. Pressure conditions in the first stage like TMP, the second stage use elevated pressure.

Table 1: Existing mechanical pulp nomenclature [Mendrala 2008]

As visible in Table 1, several different techniques to generate various pulp qualities from raw materials exist. In this work, the groundwood processes will not receive consideration, because there is no chip washing unit installed in the process. Even though the different technologies in mechanical pulping sometimes distinguish themselves from each other, depending on the technology used for the process; overall the mechanical pulping process can be divided in the following process steps:

- Chip treatment before the refining stage
- Refining
- Screening
- Reject refining
- Dewatering
- Bleaching
- Storage

As in every process that is transforming raw material into an end product, the optimum of functional interaction between the different process stages is necessary for a satisfying end result. This means that the reliability and efficiency factors of the singular stages should be as high as possible to guarantee a failure free process, maximise the cost efficiency and product quality and keep the maintenance effort as low as possible.

In the past, a lot of effort was put in optimizing the refining and screening stage to receive high quality pulp. It is a little bit surprising that this effort was not really extended to the chip washing unit. It definitely cannot be said that there were no further developments or process improvements, but a very good example for this quite small existing effort is the chip washer. Today, regarding the big players constructing washing units for the mechanical pulping market, there are few differences in the washer-designs, regardless of the manufacturing company. From various washing unit designs in the past, there is more or less only one left, which is actually in use in a big number of units. It appears that until today every manufacturer is quite satisfied with a cheap and well running unit, whose maintenance demand is very low.

1.1 Initial Situation

A well working chip-washing unit installed at the beginning of a refining process is very important for a failure free process run of the following process stages.

In the past, the scope of different technologies for washing wooden chips was quite wider than today, where there is just one technology in use by almost all big players in the pulp and paper market. The main reason for this fact can be supposed in the subordinate role which chip washing plays in the further development of new technologies. Beside some small process improvements, the main apparatus did not change in its appearance for several years. Based upon these facts it was decided in the Pulp and Paper Division of the Andritz AG in Vienna to pursue investigations in that direction.

As the whole chip washing unit consists of several different parts, the main topic of this thesis will be the chip washer itself, which can be seen as the centrepiece of the washing process.

1.2 Problem definition

As mentioned in the previous subchapter, this thesis deals with the chip-washing unit, to be more precise with the chip washer in mechanical pulping process lines. The task is to find out which technologies were developed in the past, which are presently in use and what are the differences between the actual chip washers, as far as differences are existing.

Another point is to obtain an overview of the actual washer-market situation, to work out the big players on the market and to identify possibilities to enhance the singular market share of the Andritz AG.

Also the efficiency of the actual process should be investigated, to find out if there is a connection between the washing efficiency and the service lifetime of refiner plates. This should help to find out whether there is a necessity for a further development of the chip-washing unit, in detail the chip washer to improve the process performance and how this could be realized. Therefore several different new concepts should be designed and finally one should be chosen to be elaborated in detail.

The selection criteria which are necessary to make a decision for one concept possible will be named in Chapter 5.1. The detailed view contains the generation of a 3-D model, calculations of the flow-rate, if necessary, and a short cost estimate of the costs that occur by producing the new chip-washing system.

1.3 Structure of the diploma thesis

A short insight in a refining process and a demonstration where the chip washing unit is located in a mechanical pulping process are given in "Chapter 2". The different technologies, either past technologies or technologies in use, a visualization of the existing chip washer sizes and the work out of the most common chip washer size are a part of this chapter.

"Chapter 3" is the marketing part of this thesis. A marketing research was conducted to show the different market shares of the big players on the market and to give a forecast to the possibilities for a market share enlargement of the Andritz AG.

"Chapter 4" deals with the development of new chip washing concepts, containing the requirements for a new concept. An efficiency testing model and illustrations of possible new designs are included in this chapter.

Out of this pool of new concepts a selection was made in "Chapter 5" and the selected concept is discussed in detail. Therefore advantages of this new design are worked out and 3-D models of the main parts were created and a short cost estimate for the new design is included.

The thesis is rounded up by conclusions and recommendations for dealing with this complex of themes in the future in "Chapter 6".

2 The mechanical pulping process

The raw material, which consists of wooden chips, enters the process in the chip pre-treatment stage, where the material is cleaned from contaminations, dewatered and compacted, before entering the refining stage. In the refining stage, the chips will be disintegrated in fibres and/ or fibre bundles and the so called mechanical pulp is being generated. After screening and if necessary a second refining stage, the pulp enters the dewatering stage and finally gets stored for further processing.

It is known that the chip pre-treatment stage has a main impact on the subsequent process stages. However these stages will not be discussed in this thesis, on the one hand because a detailed discussion of the different processes and refiner types would be outside the frame of this work, on the other hand because there are numerous literature sources, for example the *"Handbook for Pulp & Paper Technologists"* by Gary A. Smook [Smook 1992], or *"Mechanical Pulps: From Wood to Bleached Pulp"* by Johannes Kappel [Kappel 1999] that deal explicitly with this topic. Figure 1 visualizes where the chip treatment unit (high lined) is located in a mechanical pulping process:

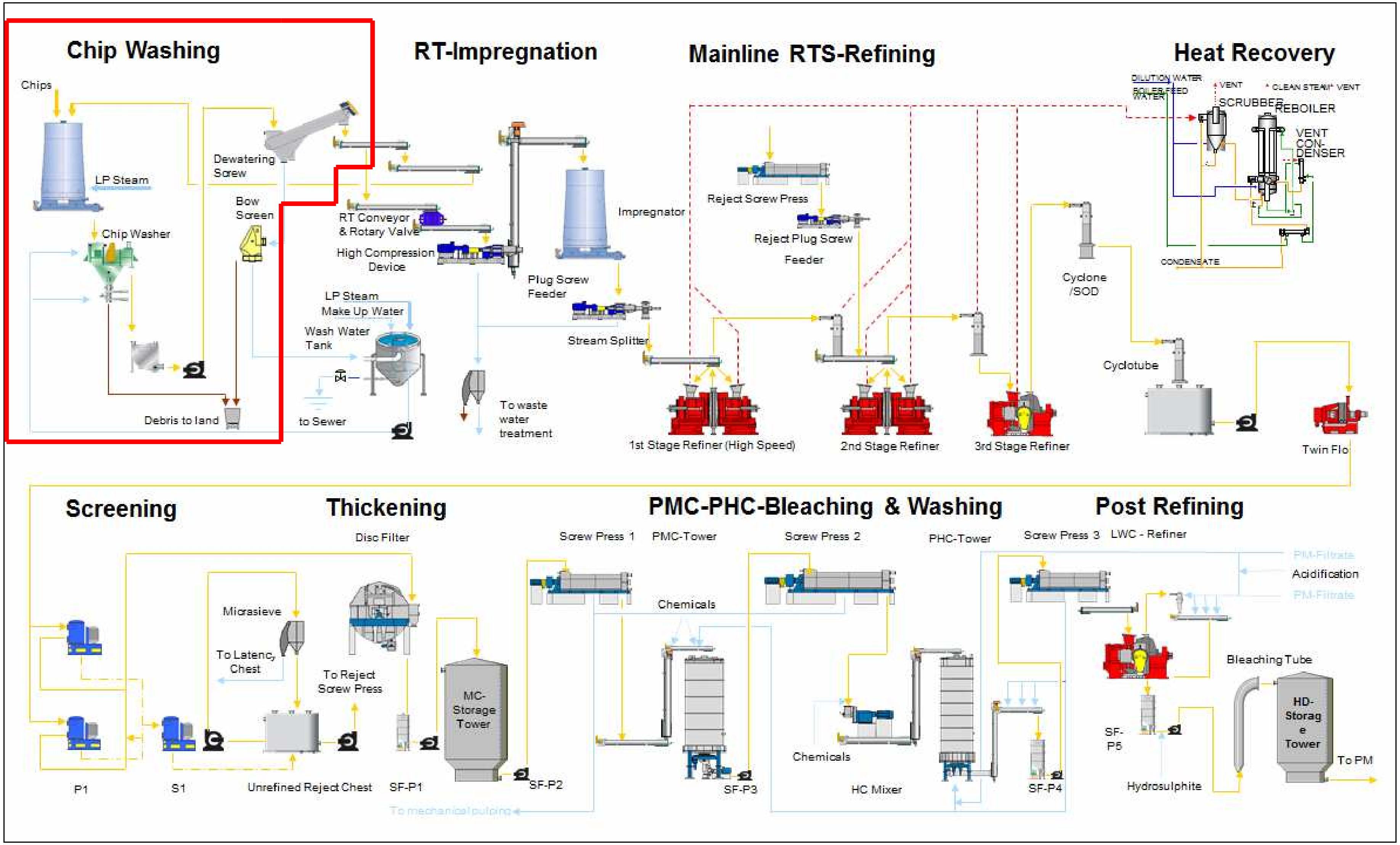

Figure 1: Example of a mechanical pulping process [RP Andritz]

2.1 Chip-washing unit

The chip-washing system is positioned at the beginning of the mechanical pulping process. A well working chip-washing system is essential for a reliable refiner operation and a minimization of the wear of the refining system, because abrasive parts like sand, stones and other solid particles will be sluiced out at this stage of the process.

As most of the systems are more or less based on the same technology, only the chip-washing system manufactured by Andritz is explained here in detail. Figure 2 shows a flow sheet of the unit manufactured by Andritz:

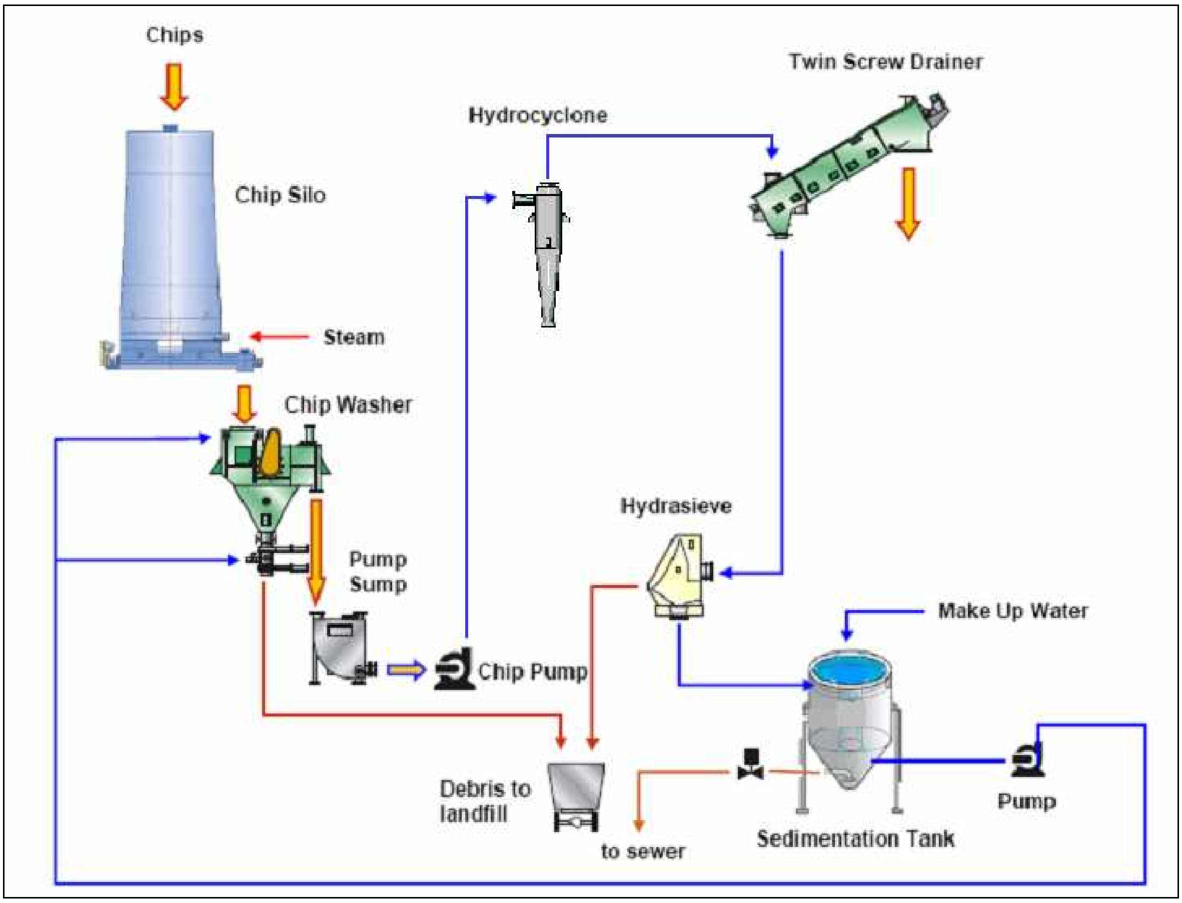

Figure 2: Flow sheet of the chip-washing process [Andritz]

The chips coming from the wood yard enter the process in a chip silo, which stores them as a buffer. The chips are almost dry when entering the silo and further the chip washer, while in some processes the chips are presteamed before entering the washer. A so called "feeder screw" is responsible for the feeding of the washer with wooden chips. Having a screw installed guarantees a constant rate of raw material entering the process. At the end of the screw, the chips fall into the upper vent of the washer, where they are blended with water. The function of a chip washer is to clean the raw material - the wooden chips - by separating them from foreign materials such as stones, metal, sand etc. The washer operates in such a way that the chip/ water mixture is agitated by a rotating paddle wheel which forces the chips under water and transports the mixture. Heavy materials sink down to the bottom of the washer where they are eliminated from the process via a sluice arrangement. For a more detailed explanation of the washer also see Chapter 2.2.2. From the chip washer, the chips are transported with a concentration of about 5% solids in the water into the chip pump-sump and with a chip pump to an optional hydro cyclone. Optional because depending on the production process and necessary purity of the chips, some processes run without a hydro cyclone. In the hydro cyclone, small particles like sand and saw dust are separated from the chips. Finally, they enter a twin screw drainer, where the solid and liquid phases are divided and the dewatered chips are transported further to the next stage of the mechanical pulping process. If there is no hydro cyclone installed in the washing process, it can be assumed that small particles get more or less eliminated with the washing water in the twin screw drainer.

The washing water is recycled in a water recycling loop; Water losses are compensated by cleaned water coming from the pulping process. In this recycling process, which is usually a three stage process (hydra sieve, sedimentation tank, pump), all contaminations like sand and small particles should be eliminated and discharged from the washing water, so that cleaned water reenters the process at the chip washer.

2.2 Chip-washing concepts

This chapter discusses various chip-washing concepts, beginning with the history of chip washing and ending with the state of the art. As it would be too extensive to take a look at all previously invented concepts, a selection was made and some examples were taken out. It could not be found out, if these previous technologies where actually in use, or just stayed theoretical inventions. The reason why they are mentioned in this work is on one hand that these examples could be helpful later in this work, when it has to be decided which of the newly developed chip-washing concepts is regarded in greater detail. On the other hand compared to the past, where various concepts where potentially available, today, nearly all of the concepts in use are based on the same principle.

2.2.1 Historical concepts

Morris, Schrader

The inventors John M. Morris and Preston H. Schrader invented this system in 1973 [Morris, Schrader, 1973].

Basically the wood chips are cleaned from foreign material such as sand and other contaminates in a vibrating water bath. The wooden chips flow through the chute for wood chip supply in the vibrating trough. The washing water is added and the water surface rises until the weir (13), with the surface still rising, is overflowed by the chip-water mixture. The mixture flows down the chute (14) and then leads in the upstream end of the screening section. When floating down, the chips pass a V-shaped diverter plate (23), where the chip flow is divided. The diverter plate doesn't reach the bottom of the constant depth section, so that sand and other heavy debris can pass to the ascending ramp section. After entering the screening section, the chips pass jets of waters through nozzles, which have an additional washing effect. At the end of the screening section the water is drained into the collector trough, while the cleaned chips are discharged over the end of the screening section. The water flows in the settling tank, where sand and non-separated particles are removed and gets recycled through the jets and the perforated deck.

Figure 3 shows the front view of the invented chip washer:

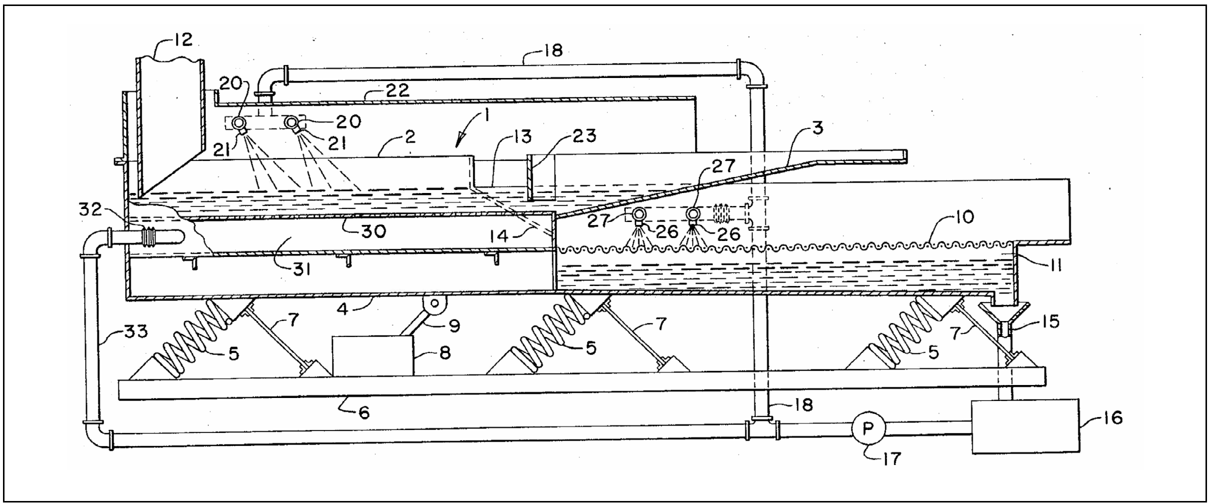

Figure 3: Wood chip washer [Morris, Schrader, 1973]

Explanation of the numbers shown in Figure 3:

1. vibratory bath container
2. constant depth section
3. ascending ramp section
4. vibratory conveyor frame
5. coupling springs
6. base
7. inclined cantilever guide springs
8. conventional driving mechanism
9. connecting rod
10. screening section
11. water collection trough
12. chute for wood chip supply
13. weir
14. chute
15. funnel and drain pipe
16. wash water settling tank
17. pump
18. pipes
19. flexible connection
20. headers
21. nozzles belonging to the headers
22. splash shield mounted on 1.
23. V-shaped diverter plate
24. laterally directed discharge trough after 23
26. jets of water from nozzles
27. headers on which nozzles are attached
30. perforated bottom
31. subjacent plenum chamber
32. flexible connection
33. pipe

Morimasa

This concept by Hanaya Morimasa from 1973 [Morimasa 1973] was invented to provide a method of washing wood chips, in which sand is easily and foreign substances could probably be completely removed from the wooden chips.

In this invention the chips are supplied to the apparatus, which is manufactured as a conical washing tank through a conveyor belt and flushed with water through a nozzle. The function of the nozzle and the upper inner blades on the stirrer is to stir the chips and to separate for example stones, metals, sand and saw dust from the chips. The pressure with which the nozzle flushes the water is so high that all the chips get suppressed under water when they enter the chip washer.

All the contaminants and heavy chips with for example sand included in the chips, or chips with a certain moisture grade sink to the region beyond the partition plate in the lower section of the washing tank. The amount of chips sinking is around 10 to 30 percent of the total amount. In this lower section, after passing a partition plate, stones, metals and heavy chips sink down to a submerged screen where another scraper is mounted. This scraper removes any sinking material with a bigger size than the screen from the screen surface. Only sand, saw dust and small particles whose size is smaller than the size of the screen holes can pass through this screen, whereby sand and heavier particles sink down into a sand trap and the saw dust is prevented from this by constant water up flow. With this process, saw dust and small sand particles get separated too, so the saw dust can be used again for pulp, or otherwise in the process and as a result, there is a smaller loss of material for the pulp production.

The scraper moves chips and heavy particles through a discharging channel forward into a selection tube where stones, metals and heavy particles sink down in a second trap and chips are moved up by a constant water flow. At the bottom of both traps sluices are installed to remove the foreign particles. The floating chips get stirred for a second time by outer blades and then via a discharge scraper and a discharge channel where they get together with the up floating chips from the lower cleaning section on a vibrating screen, where they are drained and transported to a discharging conveyor.

The water, which is used in the process, is collected in a water tank, which gets filled from dewatering the chips. This washing water is distributed by a circulation pump to the nozzle, the sand trap and the selection tube.

Figure 4 provides an explanatory picture of the Morimasa system:

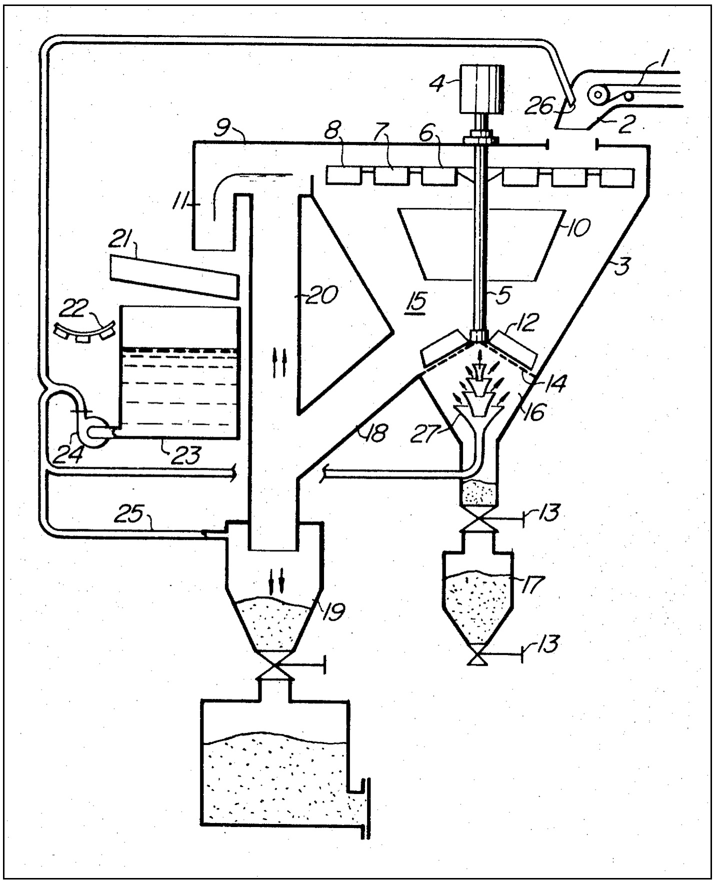

Figure 4: Morimasa chip-washing apparatus [Morimasa 1973]

Explanation of the numbers shown in Figure 4:

1. chip supplying conveyor
2. supply shoot
3. washing tank
4. stirrer driving motor
5. stirrer shaft
6. washing scraper, inner blades
7. washing scraper, outer blades
8. discharge scraper
9. discharge channel
10. partition plate
11. discharge shoot
12. scraper
13. sluice valve
14. submerged screen
15. upper first sinking tank
16. second sinking tank
17. sand trap
18. discharging tube
19. metal and stone trap
20. selection tube
21.vibrating screen
22. discharging conveyor
23. screen pit
24. circulation pump
25. stream pipe
26. jet from nozzle

Kostiainen et al.

By reference to the Morimasa invention, and other patents, Aatos Kostiainen, Ilmari Paakinen and Paavo Rantasuo invented this system in 1977 [Kostiainen et al. 1977].

Compared to previous inventions, this system requires less space than for example the Morimasa system and less washing water is needed to run the process. Also the construction is cheaper compared to other systems.

The contaminated chips are fed to the washer through an opening in the lid, opposite of the water sprays. They enter the process in the circular space between the inner wall of the cylindrical washer part and the outlet pipe. As the sprays are located tangential to the cylindrical part, the water circulates clockwise in the space mentioned above.
When the chips arrive at the sprays, they are pressed under the surface of the washing fluid. The sprays generate a circulation downstream and with this motion stones, sand and other heavy particles are detached from the chips. When the rotor is moving, it sucks the clean chips upwards in the pipe and after the rotor a part of the chip water stream is moved outwards through the outlet channel (on the picture on the right side). The chips, which are transported from the rotor to the left side of the outlet pipe, float back in the process and run through it for a second time. A funnel part is situated at the bottom of the conical part of the washer. In this funnel part, a valve is installed to sluice out scrap and heavy particles. A spray is located right above the valve which detaches chips, possibly accompanying the heavy materials and creates a turbulence to lift up the chips in the funnel part and further in the outlet pipe. By opening the valve, all sunken particles are moved out of the process.

Figure 5 illustrates the Kostiainen chip washer with its main parts and functionalities:

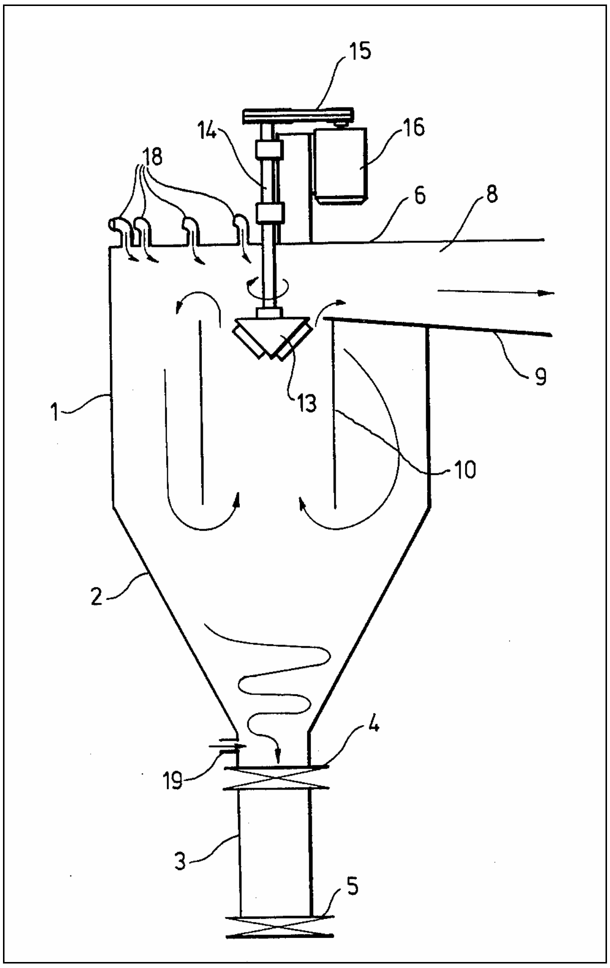

Figure 5: Kostiainen chip washer [Kostiainen 1973]

1. cylindrical upper part
2. funnel part
3. pipe
4. valve
5. valve
6. lid
7. tangential part
8. outlet channel
9. floor plate
10. outlet pipe
13. rotor
14. shaft
15. belt
16. motor
18. water sprays

Kilpeläinen

In reference to the Kostiainen washer, Ossi Kilpeläinen invented this chip-washing system in the year 1980 [Kilpeläinen 1980].

The similation with older systems is a cylindrical upper part, a conical lower part and a conduit with two valves at the bottom of the washer. The wooden chips, which are needed to be cleaned, are transported from a horizontal screw conveyor to a vertical screw conveyor, which pushes the chips under the water surface. The vertical screw conveyor carries a vane at its lower end, which causes rotation of the washing water and the chips swimming in the water.
The impurities sink down in the tank and the cleaned chips, which are floating on the water surface, are transported out of the washer by another screw conveyor. This conveyor also fulfils the function of a drainer screw. At the top end of this screw, the dewatered chips fall down a pipe and get carried forward in the process. Figure 6 shows the installation of the washer:

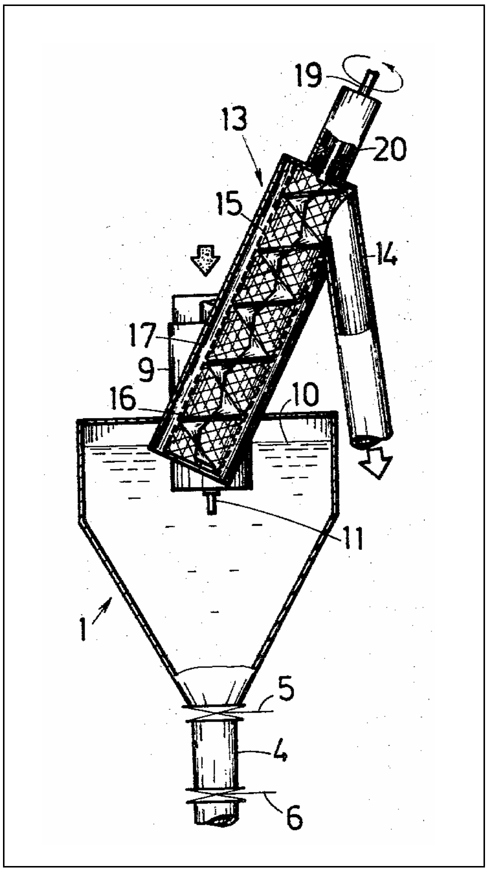

Figure 6: Improved Kostiainen chip washer [Kilpeläinen 1980]

Figure 7 illustrates the top view of the washer, where all screws are visible:

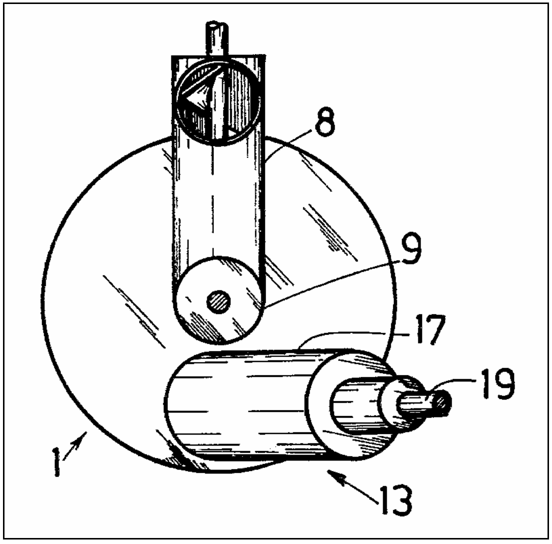

Figure 7: Top view of the improved Kostiainen chip washer

The numbers shown in Figure 6 and Figure 7 mean the following:

1. tank of the chip washer
4. conduit
5. valve
6. valve
8. screw conveyor
9. screw conveyor
10. surface of washing fluid
11. vane
12. pipe mounted over valve 5 for wash water inlet (not visible on the figures)
13. ascending screw conveyor
14. tube
15. screw
16. strainer tube
17. collecting tube
19. shaft
20. bearing for shaft 19

2.2.2 State of the art

While the last subchapter dealt with the historical concepts, this chapter focuses on the different technologies in use by several companies.

2.2.2.1 Andritz

In the Andritz unit, the chips are continuously supplied by a feeder screw from the chip silo to the chip washer. Coming from the chip storage they fall into the wash-water, get flushed with water coming from nozzles and the chips/ water suspension is agitated by a paddle wheel, where the chips are forced under water. Depending on the size of the chip washer, the number of mounted paddle wheels varies. The numbers of paddles in the different sizes are as follows:

type name	number of paddles
HE 1000	2
HE 1500	3
HE 2000	4
HE 3000	6
HE 4000	8
HE 5000	10

Table 2: Number of paddles according to chip washer sizes [Andritz internal]

During the washing process, any heavy entrained material is separated from the chips and evacuated through a sluice arrangement at the bottom of the chip washer [GD chip washer Andritz]. With this rotation movement, the chips are automatically moved to the outlet weir and forced to overrun it. From the outlet, the chip water suspension is transported further to the chip pump sump.

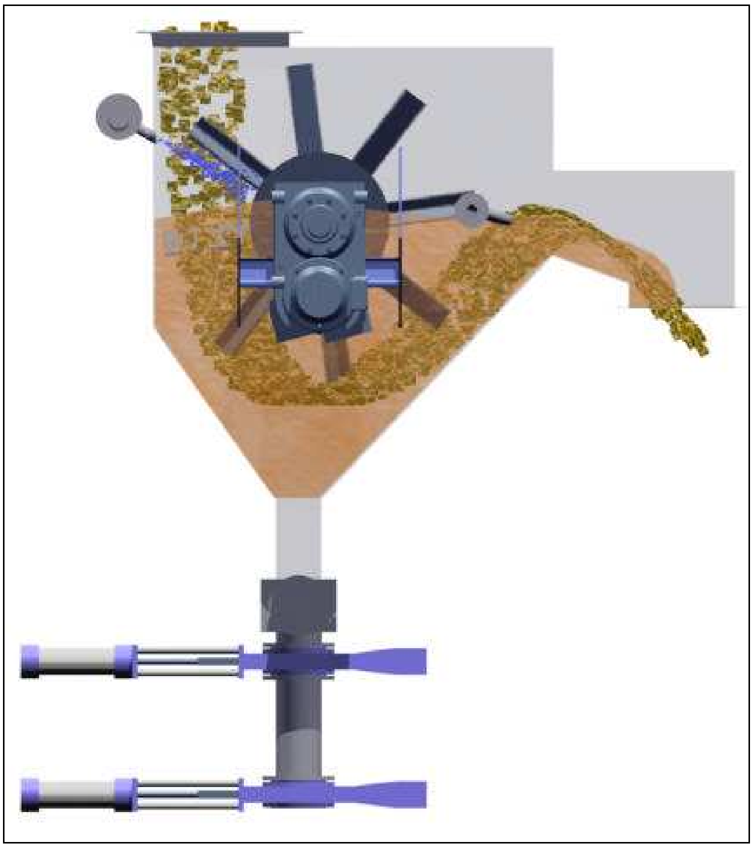

Figure 8: General description chip-washer [GD Chipwasher Andritz]

The sluice arrangement at the bottom of the washer is characterized by two valves with a wash water inlet and a flush water inlet between the two valves. The wash water inlet creates a constant upward flow to inhibit heavier wooden chips from sinking. The upward flow rate has to be adjusted in such a way that heavy particles can sink through it and get sluiced out, but the chips are kept in the process. In the process, unwanted contaminations cluster between the valves and get sluiced out. The functions of the sluice arrangement are as follows:

1. Collecting heavy material by opening the top valve.
2. Closing the top valve and opening the bottom valve, flushing out the heavy material with flush water.
3. Closing the bottom valve and opening the top valve.

These three steps are accomplished in periodical intervals. The timeframe for collecting heavy material is from 300 to 1800 seconds and for flushing from 10 to 30 seconds. The opening and closing intervals are very short [Andritz internal].

2.2.2.2 Metso

The company Metso has one chip-washing concept in their choice of products. The system called CleanMax is the latest upgrade of chip washers produced by Metso. The ChipFlume is responsible for the transport of the raw material to the washer and a part of the CleanMax system.

CleanMax

The Metso CleanMax is the latest development in chip washing [Metso Inc. 2011]. It can be installed as a completely new package, or as a custom made upgrade according to the needs of earlier installations. Figure 9 shows the flow sheet of the new CleanMax system. This system can be installed in mechanical pulping and fibreboard production. The systems may slightly differentiate from each other, depending on their requirements:

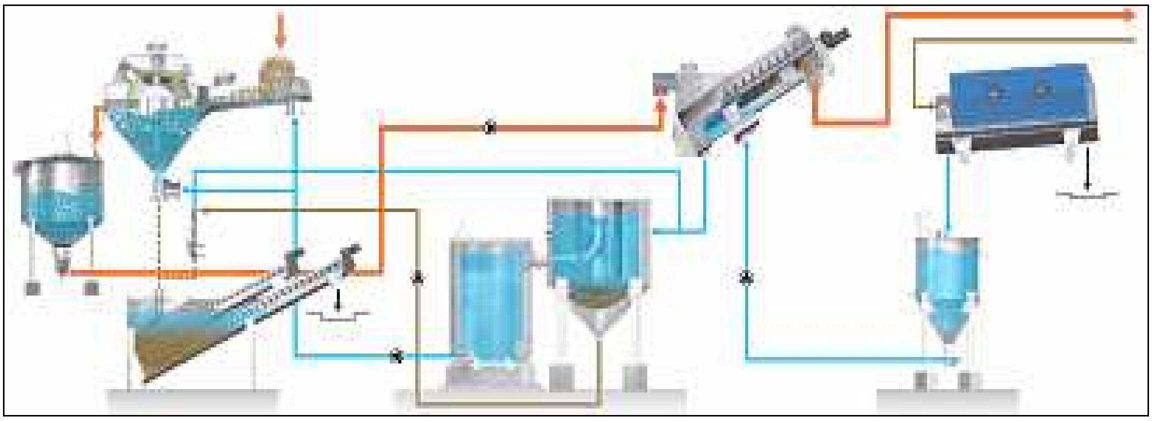

Figure 9: Metso chip-washing system CeanMax [Metso Inc. 2011]

Coming from the chip bin outside the washer where also the wash water gets added, the chips enter the process and mix up with water. Then the water chip mixture flows through a pipe to the scrap separator. The paddle drum in the scrap separator submerges the chips in the water to make sure that the separation from the contaminants is guaranteed. After that process step, the chips enter the chip pump sump and are transported further to a drainer screw where the dewatering is conducted. As can be seen in Figure 9, the wash water and heavy material separation are at the bottom end of the chip washer. The wash water coming from the drainer screw and the heavy material separation are recycled and enter the process again at the scrap separator.

Figure 10 shows a detailed view of the scrap separator:

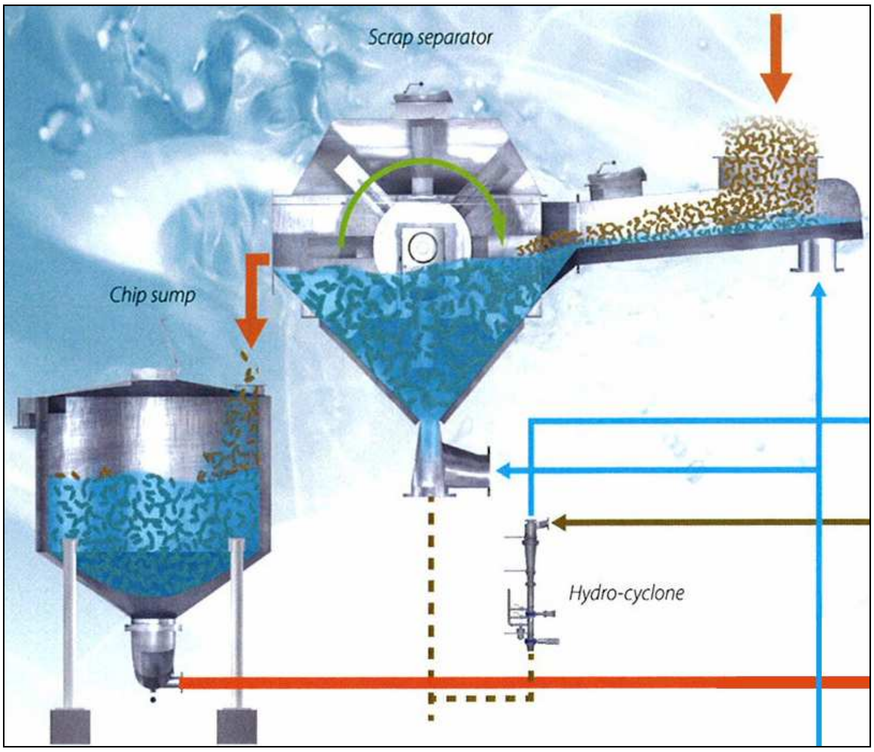

Figure 10: Detail view of Metso chipwasher CleanMax [Metso Inc. 2011]

The main features and benefits are [Metso Corp. 2011]:

- *"improved board quality, lower grit content*
- *efficient multi-stage washing*
- *low water consumption*
- *uniform chip moisture*
- *reduced wear on refiner plates, screws, cutting tools, etc.*
- *great flexibility facilitates installation layout*
- *capability to operate at high temperatures"*

ChipFlume

At Metso [Metso Corp. 2009], a common problem in the mechanical pulping mills is that caused by impurities like sand, stones and contaminated raw material, the service life of refiner plates is very short. Therefore the installation of a chip-washing unit before the scrap separator is necessary to remove sand and gravel at an early stage of the process. With the ChipFlume system, the improvement in washing provides the opportunity to produce cleaner chips or to increase capacity. In Figure 11, the main parts of the ChipFlume system are illustrated:

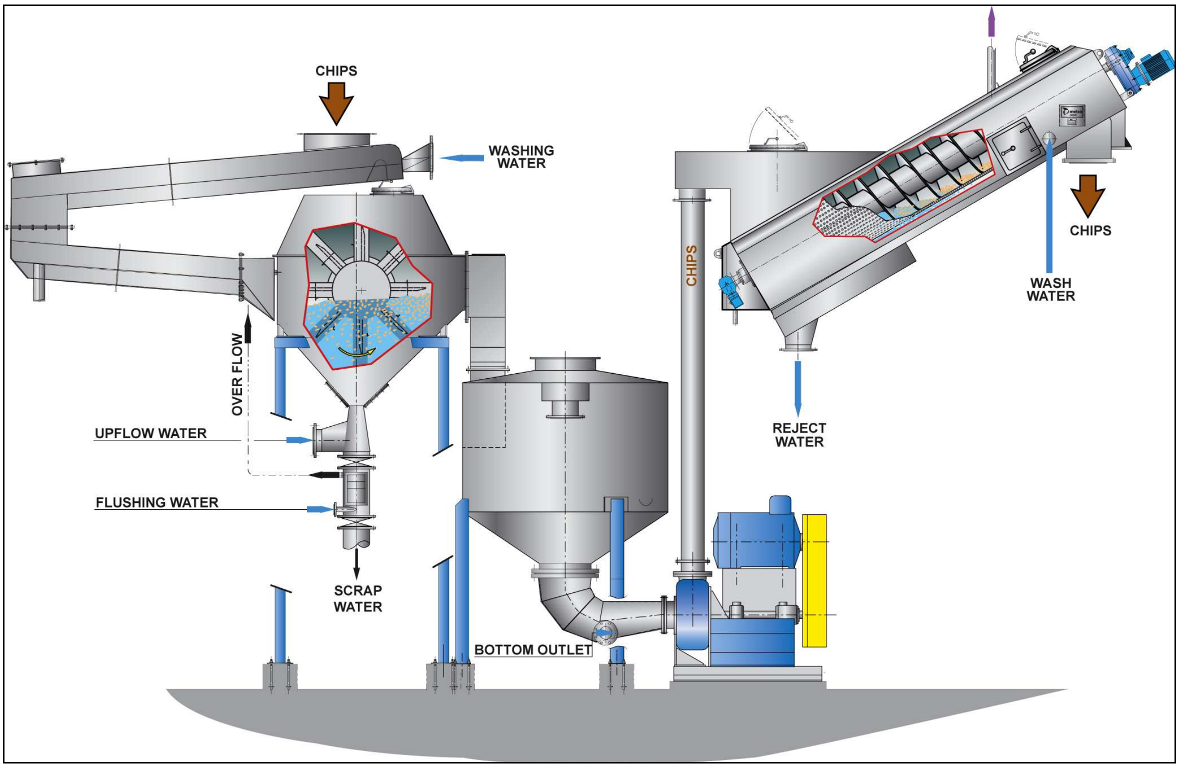

Figure 11: Metso chip-washing system Chip Flume [Metso Corp. 2009]

The ChipFlume, which that transports the chips to the scrap separator increases the retention time, because the chips get mixed up with water when they come directly from the chip bin before entering the washer. So they get mixed up better and the time span to clean the chips from heavy material is enlarged. The system can be installed in new lines or as an upgrade to already existing chip-washing units.

The advantages of the Chip Flume system are according to Metso [Metso Corp. 2009]:

- *“longer washing time*
- *increased flow with improved washing*
- *extended segment service life*
- *no moving parts*
- *fits all existing facilities*
- *minimal maintenance*
- *can be installed directly by the customer”*

2.2.2.3 Agro

Concerning the count of paddles, the chip-washing unit from the company AGRO is quite different from the other systems, because instead of one rotor it has four. Regarding the method of washing the chips, the system of Agro, shown in Figure 12, is very similar to the other concepts. The chip inlet is on the top of the washer, the chips are submerged under water, heavier particles sink down and the up floating chips are carried out of the washer on the water surface into the aqua separator.

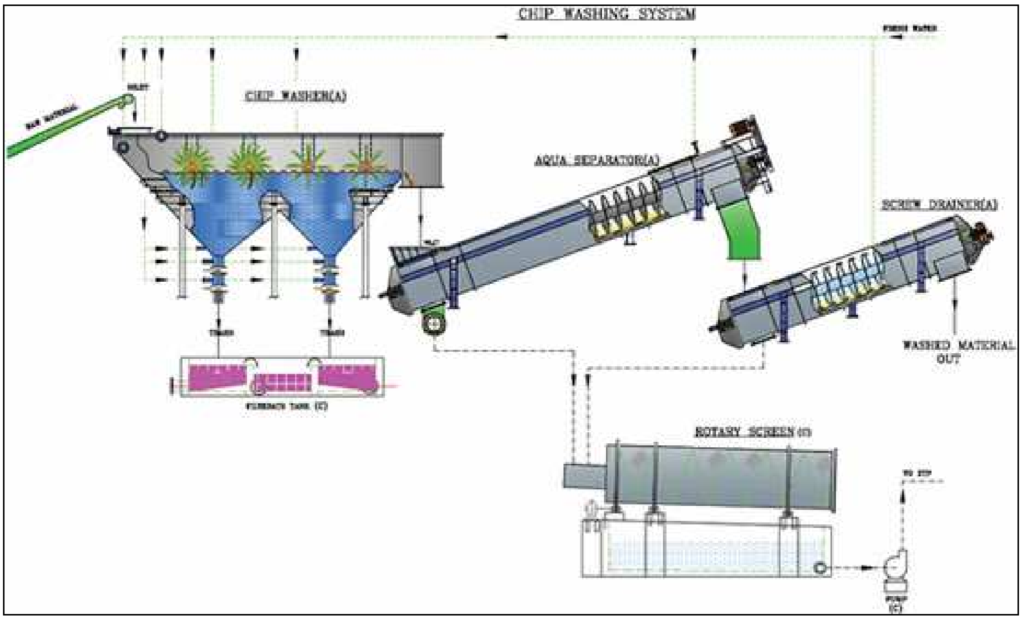

Figure 12: Agro chip-washing system [AGRO 2011]

Depending on the requirements the unit has to fulfil, the rotary screen can be replaced by a DCM screen and a HD Cleaner, and instead of the screw drainer a screw press can be installed.
It was not comprehensible how many washers based on this system are installed worldwide, but as it is a theoretically available technology it will also be considered in this work.

2.2.2.4 Pallmann

The Pallmann system is almost exclusively a fibreboard production washing system. Even though the system was not taken into consideration in the marketing research and analysis, it has to be mentioned here as state of the art, because chip washing for fibreboard and refiner processes is very similar.

The chip-washing unit is installed in front of pressurized refining systems and designed to wash chips and remove grit and contamination of heavy particles by hydraulic separation. Fine and oversized materials have to be discharged from the process before entering the washing process. In the chip washer, the chips are submerged in water and heavy materials sink down into the gravity separator. Contamination like stones and metals are eliminated through a sluice. The chips float up and flow into a chip tank (Flow sheet see Figure 13).

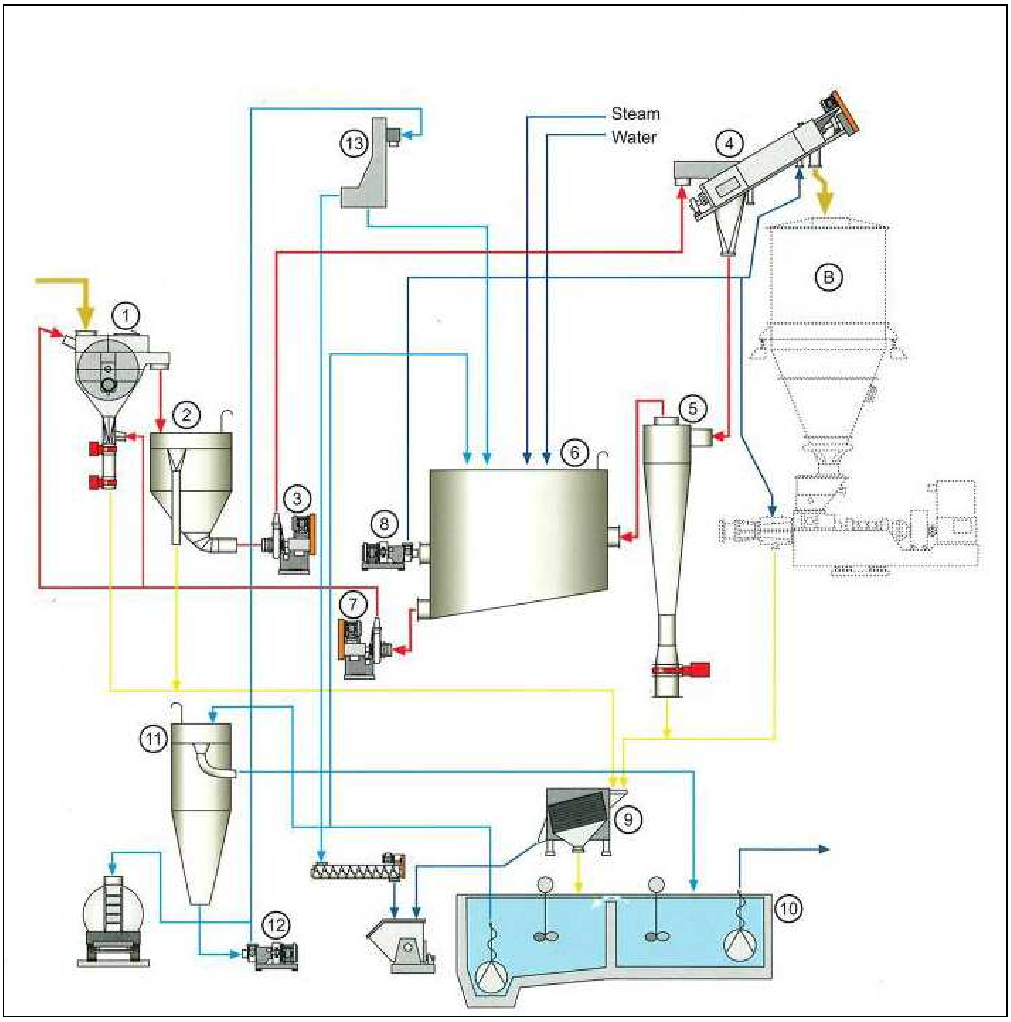

Figure 13: Pallmann chip-washing system [DI 2011]

Explanation of the numbers:

1. Chip washer
2. Chip tank
3. Chip pump
4. Dewatering screw
5. Hydro cyclone
6. Pump tank
7. Feed pump
8. Flush water tank
9. Rotary screen
10. Concrete pit
11. Settling tank
12. Slurry pump
13. Vibrating bow screen

B. Chip bin

Benefits for the customer are according to Pallmann [PWH 2003]:

- high efficient cleaning of contamination
- maximum availability
- extended use of process water
- clean and safe operation
- flexible arrangement
- lifetime of refiner segments and wear parts are maximized
- reduction of mineral content
- maintenance friendly design

2.3 Existing chip washer sizes

In the following subchapter, all the different chip washer sizes available are compared with each other to work out which are the most common sizes in use. The Pallmann system, even tough it is more or less in use just for the fiberboard production is included in the considerations, because Andritz also supplies chip washers for fiberboard production, with the same technology as for mechanical pulping. The Andritz chip washers in fiberboard production serve only as a comparison to the chip washers installed in mechanical pulping lines to find out if the most common size is the same.

2.3.1 Mechanical pulping

In the mechanical pulping process different chip washer sizes are used, depending on the requirements in capacity. Andritz offers a chip washer in six different sizes [Laser H. 2011], Metso in four [Metso Corp. 2011]. Pallmann offers three types of chip washer sizes [PWH 2003]. The reason why Andritz, Metso and Pallmann are compared with each other is based on the importance of these three companies regarding pulp and paper and the fiberboard market plant constructors. These facts are further illustrated in the marketing part of this thesis. The tables below outline the different available chip washer sizes of the three companies:

- **Andritz**

type name	number of paddles	guaranteed capacity [t/h] (t/d)	driving power [kW]
HE 1000	2	0 - 9 (0 - 216)	7.5
HE 1500	3	10 - 15 (240 - 360)	11
HE 2000	4	16 - 24 (384 - 576)	11
HE 3000	6	25 - 39 (600 - 936)	15
HE 4000	8	40 - 55 (960 – 1,320)	22
HE 5000	10	56 - ? (1,344 - ?)	30

Table 3: Chip washer sizes Andritz

The measure [t/d] refers to bone dry tons in 24 hours, the amount of added water is not included in the guaranteed capacities. It can be assumed that the competitors use the same measure and conversions.

- **Pallmann**

system type	chip washer type	Dewatering screw type	Capacity [t/h]
PWH 80	PCW 15/7	PDS 70/1	12.0
PWH 120	PCW 15/7	PDS 100/1	20.0
PWH 240	PCW 24/15	PDS 100/2	40.0

Table 4: Chip washer sizes Pallmann

- **Metso**

type name	capacity [m³/h]	driving power [kW]	
		scrap separator motor	dewatering screw motor
CWB 80	110	7.5	7.5
CWB 160	220	7.5	2 x 7.5
CWB 240	310	7.5	3 x 7.5
CWB 360	400	7.5	3 x 7.5

Table 5: Chip washer sizes Metso

For an equal comparison of Andritz, Pallmann and Metso, the measures of the capacity have to be converted into [t/h]. Andritz converts measuring units from [m³/h] into [t/h] with the following factors:

Spruce chips: 135 [kg/m³] (bone dry)
Pine: 145 - 160 [kg/m³]
Aspen: 125 - 130 [kg/m³]
Eucalyptus: 140 - 180 [kg/m³] (depends on species)

As Andritz refers the capacity to bone dry chips, a woodtype for the whole calculation and comparison has to be chosen for a conversion. Here all the calculations are made on the basis of spruce. Spruce is taken because it is a very common raw material and the density is at the bottom half of the densities mentioned above. Considering that data, the capacity of the Metso chip washers can be calculated as follows:

type name	capacity [t/h]	driving power [kW]	
		scrap separator motor	dewatering screw motor
CWB 80	14.85	7.5	7.5
CWB 160	29.7	7.5	2 x 7.5
CWB 240	41.85	7.5	3 x 7.5
CWB 360	54.0	7.5	3 x 7.5

Table 6: Converted chip washer sizes Metso

- **Summary**

Pos.	Andritz	capacity [t/h]	Pallmann	capacity [t/h]	Metso	capacity [t/h]
1	HE 1000	0 - 9				
2	HE 1500	10 - 15	PCW 15/7	12.0	CWB 80	14.85
3	HE 2000	16 - 24	PCW 15/7	20.0		
4	HE 3000	25 - 39			CWB 160	29.7
5	HE 4000	40 - 55	PCW 24/15	40.0	CWB 240 CWB 360	41.85 54.0
6	HE 5000	56 - ?				

Table 7: Relation of the different chip washer sizes

As visible in Table 7, Andritz offers the biggest scope of available chip washer sizes. It is interesting that only Andritz offers the chip washers in a capacity range. It can be assumed that the companies Metso and Pallmann often have oversized chip washers. The best way to explain this statement is with a short example:

A chip washer should be ordered for a process with the capacity of 17 t/h. By ordering from Andritz, the HE 2000 would be chosen. Even though there is a capacity range, it would fit quite well. By ordering from Metso, it would be very unlikely for the industry to choose an undersized part; you can only choose the CWB 160 with a capacity of 29.7 t/h, which could probably be overdimensioned for an optimized process. It could not be clarified why Metso and Pallmann produce these sizes, but one argument for it can probably be found in the most common process capacities, which are in use in the industry.

2.3.2 Fiberboard production

The number of chip washers installed in fiberboard lines is probably smaller than in mechanical pulping lines, because the relevance of washing the raw material is lower. As one reason for this fact it can be assumed that the pulp purity and quality does not have such high rating as it has in mechanical pulping processes. At the beginning of this chapter it is mentioned that Pallmann more or less produces washing units for the fiberboard line, but the results of the investigation are compared with the mechanical pulping lines. The reason for this is that during the investigation it could not be clarified, how many Pallmann lines were really in use worldwide, either in a mechanical pulp process or in a fiberboard process. For a better visualization of available chip washer sizes in general, the Pallmann system was compared to Andritz and Metso mechanical pulping lines.

As mentioned before, the market potential for chip washers in the fiberboard sector will not be worked out in detail in this thesis. As a consequence thereof, also the potential market volume of the fiberboard market in general has not been considered in the market analysis. A look at the install base of the different chip washer sizes was taken to compare this output with the one that was reached in investigating mechanical pulping lines and to see if the results of the marketing analysis can be confirmed.

As visible in Table 8 the most common size, which was constructed by Andritz, is the HE 3000. This means that also in fiberboard production, lines with a probable capacity of 25 to 39 t/d are in use:

type name	guaranteed capacity [t/h] (t/d)	Install base washers
HE 1000	0 - 9 (0 - 216)	
HE 1500	10 - 15 (240 - 360)	3
HE 2000	16 - 24 (384 - 576)	12
HE 3000	25 - 39 (600 - 936)	21
HE 4000	40 - 55 (960 - 1,320)	5
HE 5000	56 - ? (1344 - ?)	1

Table 8: Chip washer install base Andritz, fiberboard production [Andritz MDF]

The output shown in Table 8 was provided directly by the Andritz fiberboard division [Andritz MDF].

2.4 Most common chip washer size in use

To get an overview of which chip washer size could be in use in TMP, CTMP, APMP and RMP processes, the daily capacity of the single mechanical pulping lines were taken from the Jaako Pöyry database [Pöyry 2011a]. This visualized which capacity a possible installed chip washer must guarantee to run the process. Then these results were compared with the choice of products from Andritz. With these data it is possible to rate each Andritz product on the basis of the whole market to work out a potential install base for a product upgrade or a new invention. As seen in Figure 14, with a new invention for the HE 1000 washer for example, 53% of the mechanical pulping lines could be reached.

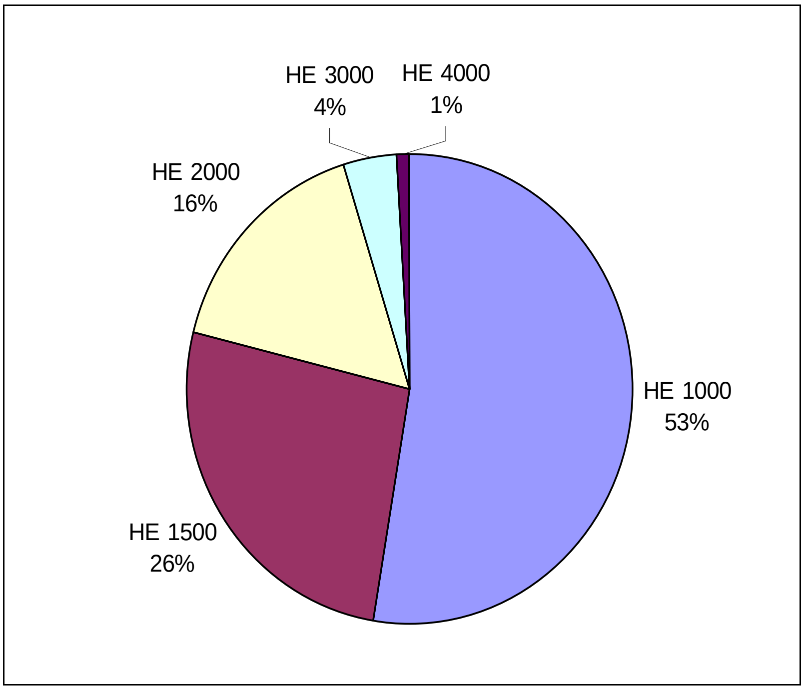

Figure 14: Most common chip washer sizes in mechanical pulping

For several reasons before choosing a size for a new invention or product upgrade, Figure 14 has to be questioned critically. On the one hand, the competitors do not manufacture a chip washer that has the same size as the HE 1000. The smallest size produced by them is similar to the HE 2000. It is therefore implausible that Andritz manufactured all chip washers worldwide with a capacity of up to 216 t/d. It is more likely that for example Metso installed a chip washer for 356 t/d in a line whose capacity is up to 216 t/d. This means that it cannot be determined, whether the size of the chip washer fits exactly to the capacity of the mechanical pulping line. On the other hand, in reference to the assumptions made at the beginning of the marketing analysis in Chapter 3, it is not sure whether the amount of chip washers, which is the base for calculating the ratios, is indeed installed.

As the results from this analysis can be seen as insecure, because of the reasons mentioned above, further investigations were carried out. Sourcing an overall install base list from the Andritz - paper service unit (PS unit) delivers the results, which is illustrated in Figure 15:

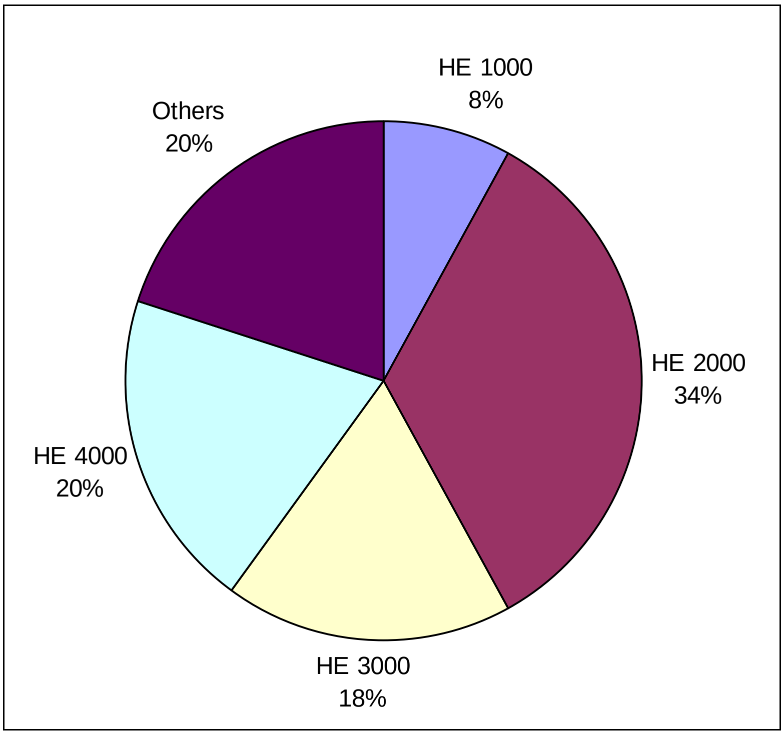

Figure 15: Chip washer sizes by installation base of the service unit [PS 2011]

It has to be mentioned that the reason why the PS unit had to deal with these washers was not investigated. For a detailed consideration this could be necessary, but to get an overview, this data is acceptable.

It can be summarized that with the ratios shown in Figure 14 and Figure 15, the most common chip washer sizes installed by the company Andritz are the sizes HE 2000 and HE 3000. Overall and under the asumptions mentioned above, the sizes with a capacity of 384 - 576 t/d and 600 - 936 t/d are probably installed in a large number.

This assumption is validated by the fact that also in fiberboard production, the most common sizes, installed by Andritz, are the HE 2000 and the HE 3000 (see also Table 8).

3 Marketing Research

A marketing research study is the most common way to define the individual market share of the viewed company and to show opportunities for companies in a certain business division. In this chapter, the overall chip washer market is investigated to work out the specific market shares. It can be divided in two parts. In the first part, two different marketing research strategies are presented and a short explanation is provided on how the chip-washing research was conducted.

The second part of this chapter deals with the chip-washing marketing research itself. This part consists of assumptions made, the different data sources used and finally the forecast for future developments and conclusions.

3.1 Introduction to marketing research strategies

It is for sure that there are several different ways to conduct a marketing research. In this work, the theoretical background for the research is taken from "*Grundlagen des Marketing*" by Philip Kotler et al. [Kotler et al. 2003] and "*Marktforschung*" by Ludwig Berenkoven et al. [Berenkoven et al. 2009].

Marketing research is principally the connecting link between the marketing department, the customers and the public. The information sourced is needed to

- distinguish chances and problems of the marketing sector
- create actions and test them
- measure the impact of the company's marketing
- understand the marketing happenings.

Marketing research is a very important tool for companies, who are considering new inventions, an enlargement of their product portfolio or a new strategic orientation, because it provides forecasts for market potentials and future market shares.

3.2 Procedure of a marketing research proposal

Today, there are several practises in use for executing a marketing research. The amount of literature regarding this topic is very large. As it would be too extensive in the scope of this thesis, to discuss the various methods, two different theoretical approaches, of conducting a marketing research, which were in use for achieving the results, will be presented in this subchapter.

3.2.1 Modus operandi by Kotler

[Kotler et al. 2003] characterize a marketing research study by four steps:

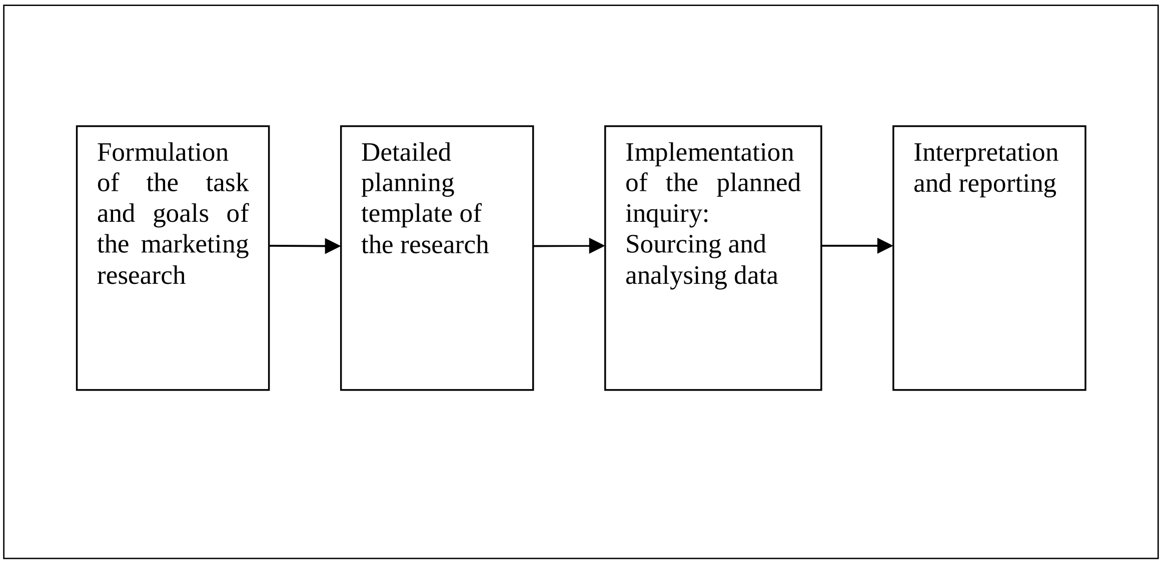

Figure 16: Procedure of a marketing research [Kotler et al. 2003]

The individual steps are described as follows [Kotler et al. 2003]:

Formulation of the task and goals of the marketing research

Marketing managers and researchers have to work closely together to exactly define the task. This step can be seen as the most difficult task in the whole marketing research process. It has to be decided whether the study will be realized with internal manpower, or with external institutes or experts. Depending on the needed outcome and the free

manpower resources within a company, this decision should be well considered. For this step, enough time should be planned to get a clear overview of the things to do.
For a research project, three main types of target statements exist:

1. An approximate primary investigation should collect information, which supports the problem definition and solution approaches.
2. The second type, the describing marketing research, deals with the question of how large a certain market potential is.
3. The third type is the so called cause’s research. Here for example several hypotheses for a certain project are tested.

The first formulation of the goals dominates the whole research work.

Detailed planning template of the research

The second step in a marketing research study requires a detailed description of the needed information, to develop a plan on how to get the information and finally present that plan to the marketing division. The plan shows the origin of the data at hand and explains the resources, methods and instruments used for the project.
Two methods for sourcing data and implementing a marketing research study can be distinguished:
The first method is primary marketing research, where the direct contact to customers, producers and merchants is sought by using the telephone, the internet, a questionnaire or direct contact. Another method is secondary marketing research, where the sourcing is confined to databases, libraries or comparable data sources.

Implementation of the planned inquiry: Sourcing and analysing data

After defining which sort of marketing research, or whether a mixture of primary and secondary research is used, the inquiry is implemented. A very important factor here is the quality and propriety of the sourced data. On the one hand, because with these factors the validity of the research is measured and on the other hand sourcing is the most cost intensive factor of the whole study. The replicability and reliability of the data sourced must be guaranteed at all times. Especially in a primary research, fake data received from samples of surveys has to be filtered out, in order not to endanger the validity of the results received.

Interpretation and reporting

The last point of a marketing research is to interpret the results to draw conclusions and to report the results to the management. The results should be worked out as simple and clear as possible, to avoid misunderstandings between the realizing part (persons who work on the research study) and the management. The interpretation and reporting is also a very important phase in a marketing research process, because it serves as a basis for future actions, usually defined by the management. Therefore the management must be certain that the presented results are valid and all requirements have been fulfilled. Another very important point is that the management accepts the provided results, even when they expected the results to be different. Otherwise the results of the study will be falsified.

3.2.2 Modus operandi by Berenkoven

[Berenkoven et al. 2009] describe the ideal marketing research process as shown in Figure 17:

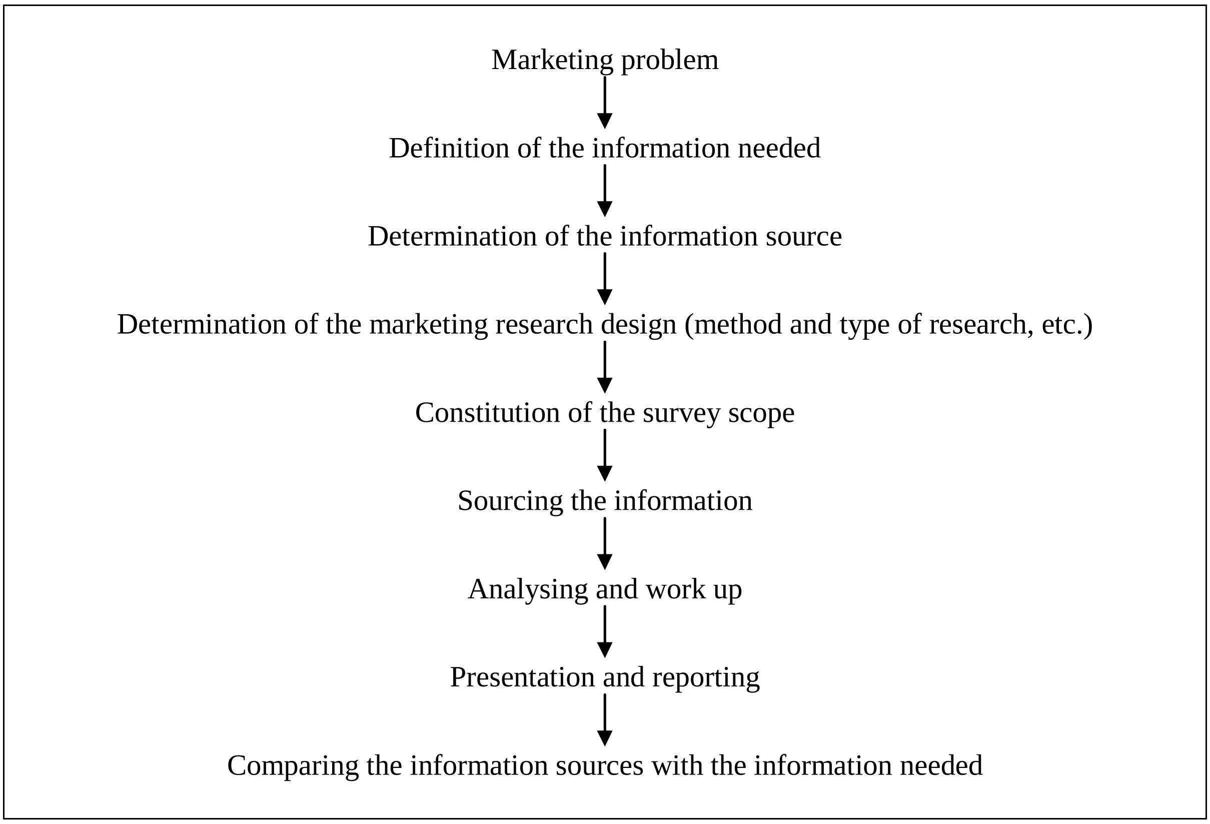

Figure 17: Ideal marketing research process [Berenkoven et al. 2009]

The first step of the process consists of stating the task for the research. After defining the problem of sourcing the information, the main goals to achieve are fixed and the information sources are determined. Basically various primary or secondary resources can be used. The decision of which resources will be used is made subsequently, depending on the necessary quality of the research results, the time and cost effort and also the number of persons, who can work on the research.

The constitution of the survey scope contains for example the structure of a questionnaire, the parameter of an experiment, etc.

Another point which has to be clarified is whether the marketing research can be conducted internally, or, if the personnel capacity is not available, an external marketing research institute has to be hired. At the end of a research, all results have to be evaluated, analysed

and interpreted. The analysed results build the basis for the solution of the previously defined problems.
This theoretical method will for sure be modified and fitted to the specific requirements of companies in the practical applications.

3.3 Implementation of the research

Taking into account the theoretical background, the marketing research in this thesis followed more or less the milestones mentioned by Kotler and Berenkoven, even though they were not worked out in the form of the schemes shown in the previous subchapters. It won't be shown in detail in the following subchapters how the results were produced, because it would go beyond the scope of the work, but all references for the below mentioned arguments are available and can be reproduced if necessary.

As the main goal was to get an overall feeling for the market share of the Andritz AG, it has been decided to make a desk research. The reasons for conducting this kind of marketing research are very simple. The biggest argument is that just an overview was required as a result. As two sources with a very broad and detailed database concerning the pulp and paper industry were at hand, an Andritz internal source and the Jaako Pöyry database, it was obvious to get information for the marketing research out of these databases. These two were compared with each other to work out whether the outcome of the research can be seen as representative. It also has to be considered, that the marketing research is not the main focus in this thesis. Therefore a primary research would be too labour- and time- intensive and this effort cannot be justified. This supports the argument for conducting a desk research.

Finally the results are figured out and the development of mechanical pulping lines in the future is predicted from the data at hand.

3.4 Assumptions made for the specific chip washer marketing research

Because of the present data situation, the following assumptions have to be made to accomplish a marketing research:

1. The focus is placed on mechanical pulping processes, because chip washing plays a very important role in these processes. The author is aware of the fact that chip-washing units are installed in chemical pulping processes, but the importance of chip washing in chemical pulping can be considered as being not that significant as in mechanical pulping.

2. To get a feeling for the number of chip washers in use, it is supposed that every installed mechanical pulping line has its own chip-washing unit, at least its own chip washer.

3. The predictor for a mechanical pulping line and additionally for an installed chip washer is a primary refiner.

4. There are several different data sources for the number of refining processes installed all over the world. In this thesis, the specific market share of Andritz is calculated from an internal data source, which is the basis for most strategic deliberations in the paper service engineering unit.

5. The temporarily shut down mills with no restart date are not considered, because as it is not certain whether or when they will be restarted, they currently have no influence on the market potential for the chip-washing unit.

3.5 Data sources

During the research, two main data sources provided to be as the most reliable ones. First, an Andritz internal source, hosted by the vendors of the company [Andritz] and the second source is the Jaako Pöyry database [Pöyry 2011, Pöyry 2011a]. With these sources, the Andritz market share will be worked out and forecasts will be predicted.

A short sidestep will be made into the fibreboard production, because being a mechanical disintegration process it is possible that a fibreboard line has a chip-washing unit too. The number of potential chip-washing units installed in Andritz medium density fibreboard (MDF) lines has no influence on the Andritz market share in mechanical pulping, but as the technology is nearly the same, it has to be included in the potential market forecast for a new chip washer concept to work out the full potential.

The data source for the install base of MDF comes from Andritz internal sources [Andritz MDF] and will not be evaluated in detail. The sense is just to give an overview of how many chip washers are installed in Andritz lines and compare the received data with the mechanical pulping lines to support their plausibility.

3.5.1 Andritz

Figure 18 shows the manufacturers of the individual refiner lines. The shares have been worked out from the Andritz internal source. The processes which are faced, enclosed in the research work and shown in the figure are TMP, CTMP, RTS, PRC-APMP, BCTMP, NSSC, RMP and CSRMP processes. The reason to confine the research to these processes is that for these processes the most valid data is available. The received data can be seen as sufficient to give an overview of the market.

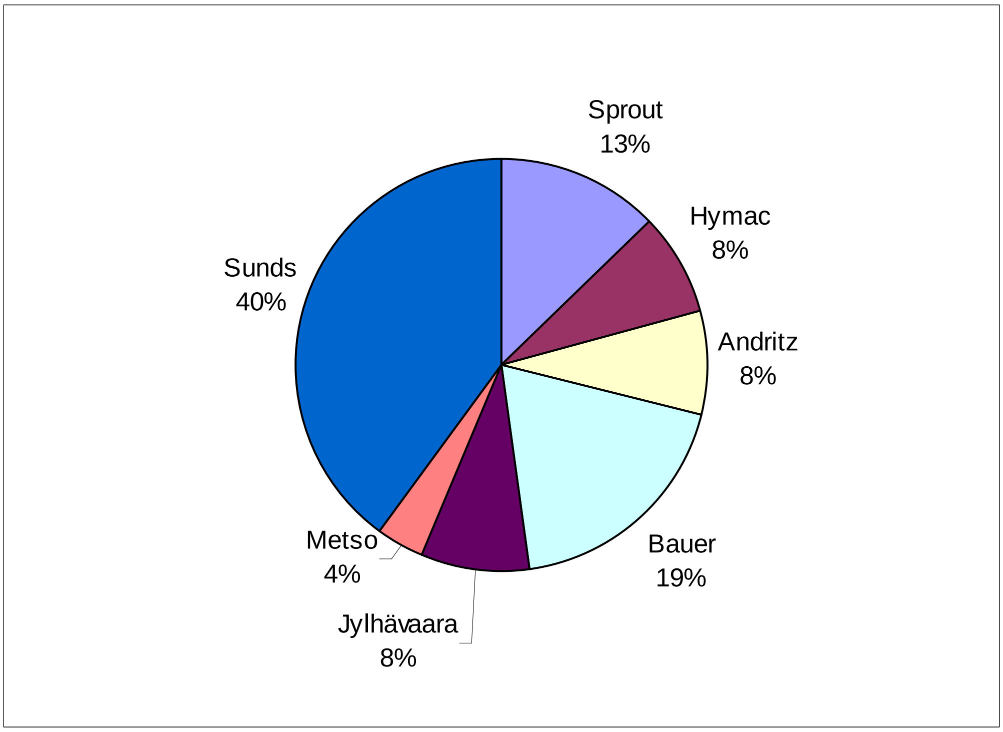

Figure 18: Market share by manufacturers for mechanical pulping lines [Andritz]

With Andritz taking over Sprout, Bauer and Hymac [ANDRITZ HISTORY 2011], and Metso's acquisition of Sunds and Jylhävaara, the market situation changed. From seven competitors in the past, the market is currently dominated by these two big players. Actually there are about 449 primary refiners in use worldwide. As said before, it is assumed that every refiner has at least one chip washer implemented.

Figure 19 shows today's specific market share of the two companies:

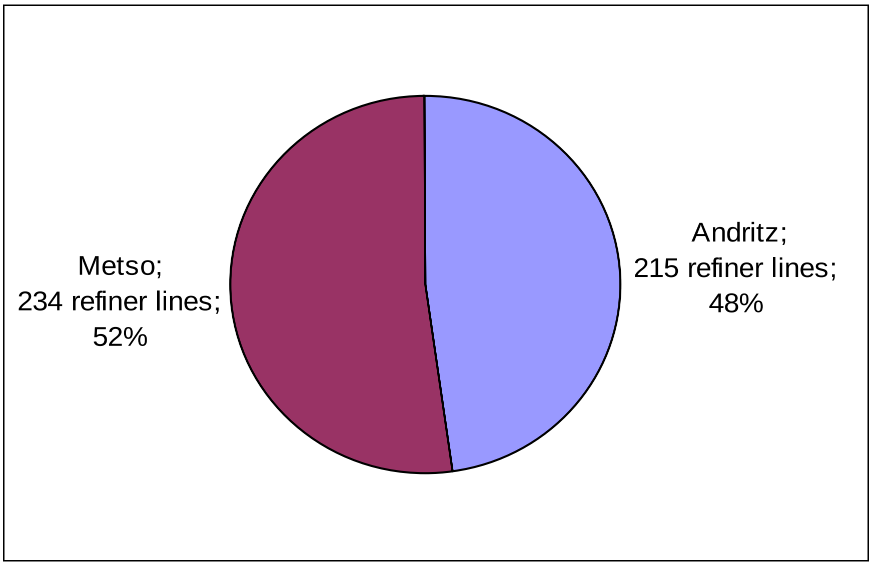

Figure 19: Present market share and players, mechanical pulping [Andritz]

The timeframe of Figure 18 and Figure 19 is from about 1945 until today.

3.5.2 Jaako Pöyry

The Jaako Pöyry results of searching for refiner lines are taken as a reference for the validity of the Andritz data.
While sourcing the Jaako Pöyry database, two possibilities for searching for refiner lines became apparent. The first one is to search for installed pulp mills for mechanical processes [Pöyry 2011] and the second is to search directly for mechanical pulping lines [Pöyry 2011a].

Interesting is that two different results appeared as outcome with these two methods. In this case, TMP, CTMP; RMP, PRMP and APMP processes were examined.
Searching for pulp mills resulted in 365 installed lines in pulp mills. Searching directly for mechanical pulping lines had an outcome of 369 installed lines. As the search results distinguished themselves by 4 refining lines, a decision had to be taken on which data source would be used for calculating the marketing share. The source data of mechanical pulping lines is more detailed, and therefore will be used for further evaluations.

Figure 20 shows the original manufacturer of mechanical pulping lines in use worldwide, in a data range from 1954 till 2010.

Companies whose installation base is so small that they don't have any influence on the market are not depicted in the following Figure, but they are considered in Figure 21, pooled in the share of "Others".

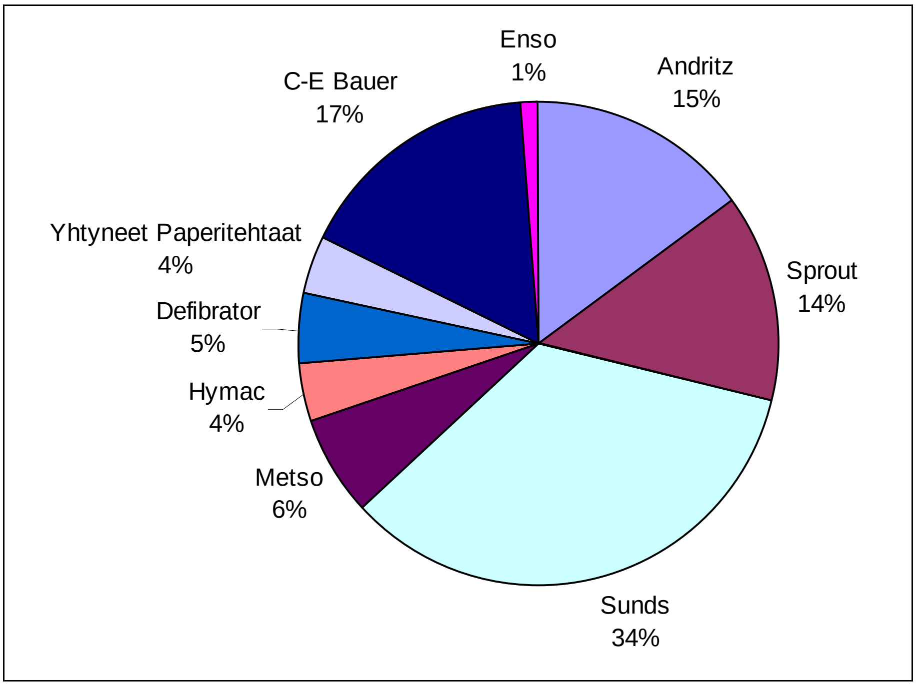

Figure 20: Market share by manufacturers for mechanical pulping lines [Pöyry 2011a]

With Andritz taking over Sprout, Bauer and Hymac, and Metso Sunds and Defibrator, the market situation changed.

The different market shares of these companies are presented in Figure 21. As mentioned before, the rate of “Others” contains cooperations between companies, unknown producers and different companies’ own productions pooled in one market share.

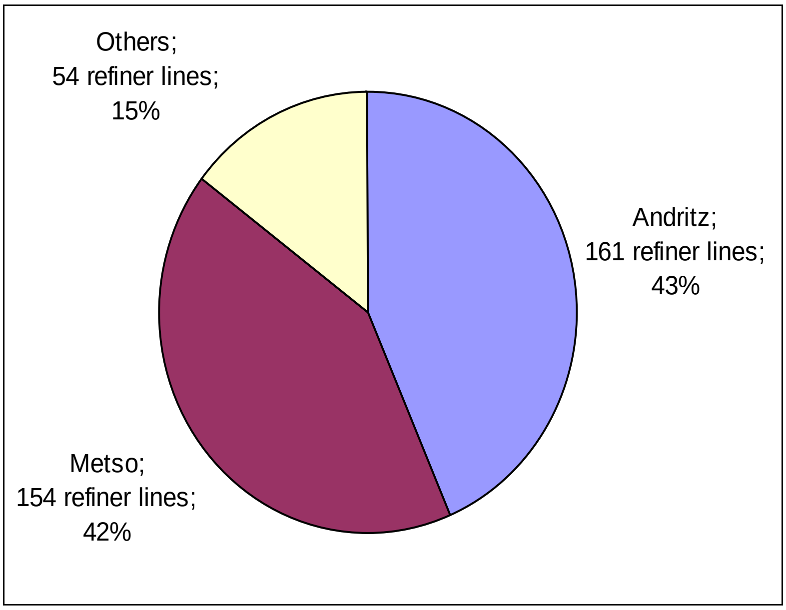

Figure 21: Present market share and players, mechanical pulping lines [Pöyry 2011a]

3.6 Conclusions and potential chip washer market forecast

For a plausibility comparison of the Andritz internal and the Jaako Pöyry database to assess the market volume, just those processes are viewed that are identical. These are the TMP, CTMP, APMP and RMP processes. Searching the Jaako Pöyry database results in 369 such refiner lines worldwide, while Andritz reports 375. The difference of six lines worldwide can be seen as negligible when the focus is placed on the whole market. The reason for this difference can be found in the different actuality of data and the probably different ways of sourcing data by these two companies, because in each list slight differences are recognizable, concerning the manufacturers and their singular install bases. But in the end, the validity of the Andritz data overall could be proven.

As a result of the data at hand, the present potential market in mechanical pulping for service business lies at 449 mechanical pulping lines worldwide. This means that including the assumptions made at the beginning of this chapter, 449 chip washers from different manufacturers are potentially installed worldwide. The different market shares are taken from the overall mechanical pulping processes data provided by Andritz and it is visible that the Andritz share lies at 215 refiner lines or 48% and the overall Metso share counts 52% or 234 installed lines.

Facing the data from Jaako Pöyry [Pöyry 2011], the consumption of paper on the global market in the last five years has shown an increase in China, a decrease with a slight recovery in North America, the rest of Asia and Western Europe and a rather steady level in the rest of the world. It can be assumed that in the next years China will still raise the consumption of paper provided that the economy grows as fast as in the last years and the consumption of the rest of the world will stay more or less steady.

This thesis is supported by the fact that as visible in Appendix 1 and summarized in Figure 22, most of the new projects are located in China, followed by the rest of Asia and Eastern Europe. The projects can either be restarting a mill, expanding the capacity, installing a new line or installing a new mill.

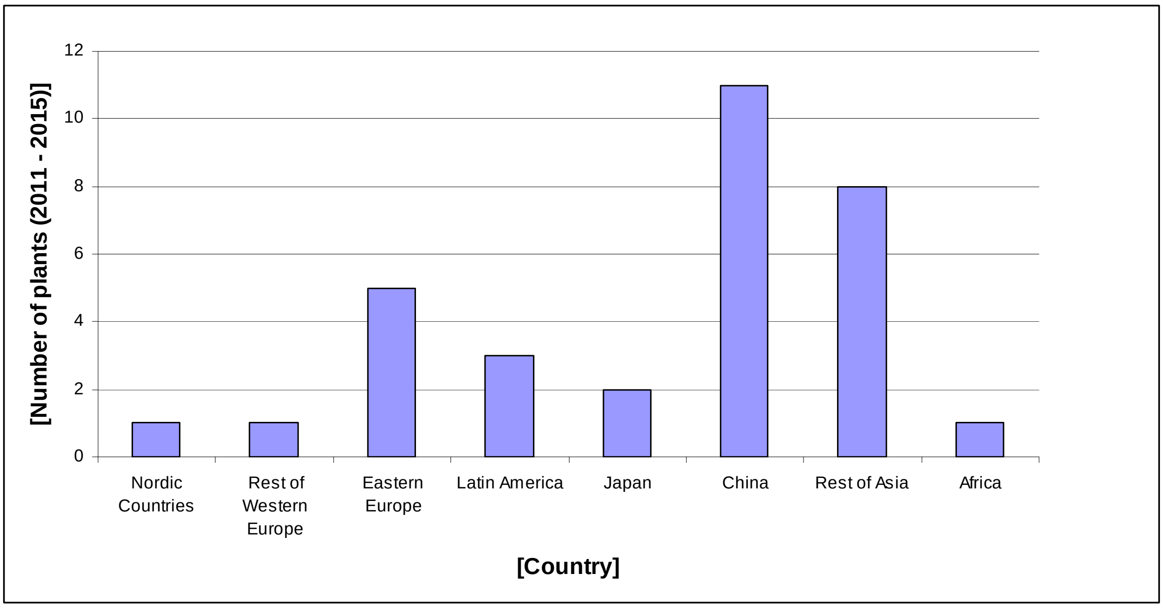

Figure 22: Summary of mechanical pulp capacity changes by country

The unknown factors are India, because no separate chart is available for this country and maybe Africa, where the political situation in the African countries has a key impact on the growth of the economies.

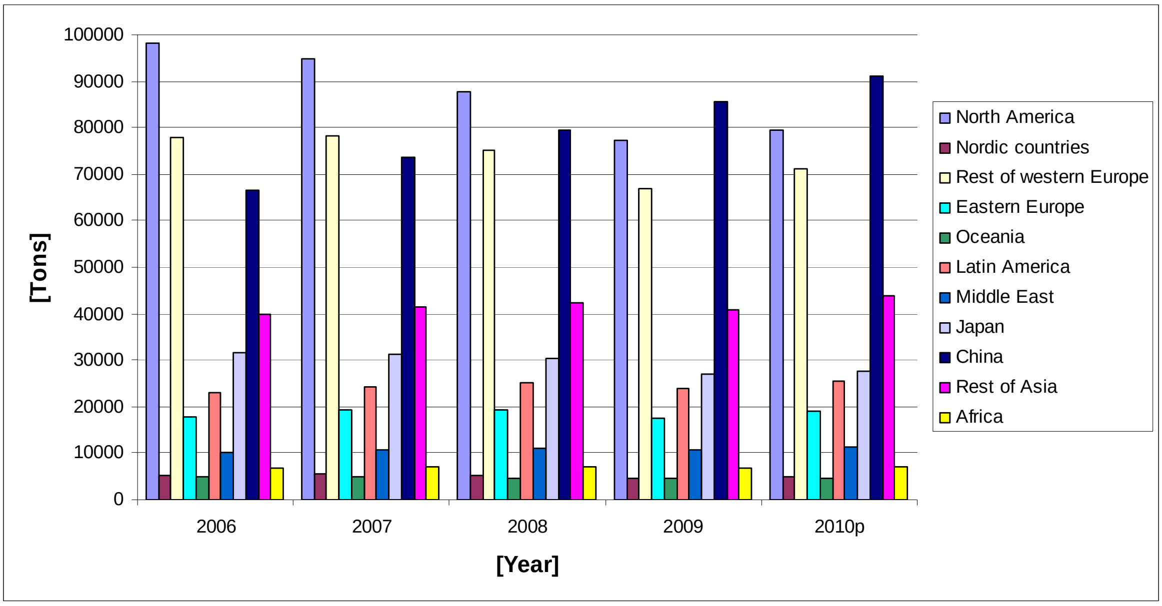

Figure 23: World total consumption of paper & paperboard

Considering Appendix 1 [Pöyry 2011] it is planned or just decided to enlarge the capacity of four mills, build 16 new, restart three mills and start with 12 new lines within the next five years. In these cases it concerns mechanical pulping processes, like CTMP and SCMP processes. If a potential enlargement of mills is also planned for chemical pulping processes, it is not part of the investigations made.

With the fact that the design of the present chip-washing units is very similar, there is a high potential for a possible relaunch and improvement of the existing chip-washing system.

4 Development of new chip-washing concepts

After reviewing the past inventions and the state of the art, the basics for a further development or a new invention will be presented in this chapter. The chapter is subdivided into a functional specification document which a new system has to fulfil, a quantification of the efficiency of the washing process which is necessary in the future to show improvements compared with the old system, theoretical calculations that have to be considered when a new system is designed and finally, based on all the points mentioned above, newly found concepts will be illustrated.

4.1 Functional specification document

In this work, the term functional specification document refers to all the requirements a new concept has to fulfil to be seen as an improvement of the old system. In the early beginning of the conceptional phase, these points did not play a role. First it had to be clarified, which technical possibilities are existent for a further development. During the assortment of the concept sketches, these criteria became obvious. For further information on this point also see Chapter 5. The main requirements for a further development or a new invention are:

- Performance improvement of the washing process
- Better and earlier sand separation
- Maintenance effort should be low
- Concept should fit in existing washing lines
- Concept should be installable in every common process size
- Reduction of water consumption
- Reduced energy consumption

The performance improvement of the new chip washer can only be theoretically estimated in this work, because to validate a performance improvement the new system has to be installed in a production line and the efficiency of the washing process before and after the installation of the new system has to be measured. But these estimations are elementary for thinking about an improvement. As in the existing washing process most of the sand gets sluiced out of the process in the drainer screw, an earlier point in the process should be defined to reduce sand. Therefore a technical solution has to be found. The maintenance effort in the new system has to be as low as in the existing one, but the size and the float rate of a concept to be found have to be similar to existing washer types and it must be possible to install the new washer in existing lines. Another benefit would be if the water consumption was decreased and the process could be run at a low energy need.

If the need of energy and water consumption cannot be reduced, the benefits of the new system, measured for example with saving costs for wear equipment and the costs for more energy have to be contrasted to point out if the installation of a new system is more economic.

4.2 Quantification of the efficiency in the washing process

In the year 2008 Andritz commissioned a diploma thesis [Mendrala 2008] to investigate the ash content (sand) and the efficiency in the washing process at different mechanical pulp and fibre lines. In that thesis, investigations were carried out at nine different companies all over Europe, where different technologies are in use to produce mechanical pulp, or fibreboard. Except for one factory (Homanit in Losheim), all have a chip washing unit installed. To quantify the efficiency in the washing process, two methods were used to take samples.

These methods are called *"Method I"* and *"Method II"* and that nomination is also applied in this work. The difference between these two methods is that the sample size and the amount of samples taken vary. The ash contents after combustion of the wooden chip samples are measured at the beginning of the process, where the chips enter the chip bin, and at the end, where the chips leave the dewatering screw. These ash contents were compared with each other to calculate the efficiency. The sampling points were defined at the beginning of the experiments and the same for each evaluated company.

As the author mentions, taking samples with the first method cannot describe the efficiency, because there were not enough samples taken and the sample size was too small, so all the data presented in this work refers to the second method, called

“Method II”. Each method of measuring the efficiency was conducted by reference to the TAPPI rules T211 om-02 *“Ash in wood, pulp, paper and paperboard: combustion at 525 °C”* and T413 om-06 *“Ash in wood, pulp, paper and paperboard: combustion at 900 °C”* [Mendrala 2008].

The ash content was obtained via the following steps:

- Heating up the muffle furnace to the requested temperature;
- Porcelain pan has to be dried for about 30 minutes in the compartment drier and to be cooled down in the desiccator;
- Balancing out the cooled down pans to 0.0001 g;
- Putting the dried sample in the pan;
- Covering up the ash pan with the lid and placing it in the muffle furnace;
- Burning the sample with closed lid in the furnace for about 10 min.;
- After 10 min. replacing the lid and starting the incineration; the incineration time takes about two hours;
- After the incineration, cooling down the pan in the desiccator;
- Balancing out the cooled down pans to 0.0001 g;
- The determination always has to be conducted twice;

Figure 24 shows a flow sheet where all the sampling points are marked:

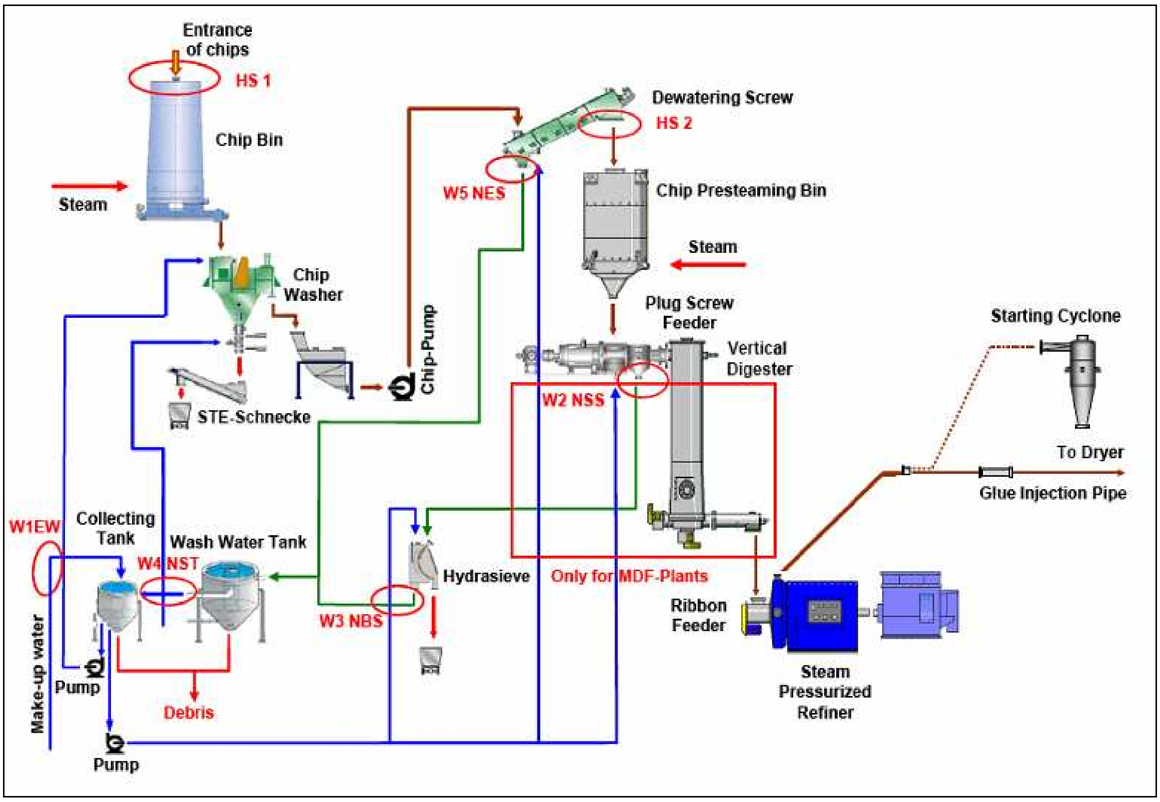

Figure 24: Sampling points of MDF & TMP plants [Mendrala 2008]

The efficiency of the washing process gives an impression of the reduction of contaminations during and after the washing.

The results of the work are as follows [Mendrala 2008]:

An efficient process can enlarge the lifetime and preserve the refiner plates from damages caused by impurities in the medium, but it has to be considered that the lifetime of refiner plates is not only depending on the washing process. The qualities of wooden chips, respectively the quantum of contaminations are also a very important factor, considering the life time of refiner plates. Depending on the method of taking the samples, the efficiency of washing varies between 90.3% and 14%. The temperature plays another very important role in the TMP process [Mendrala 2008]. The higher the temperature is the more efficient is the washing process. A high temperature softens and prepares the wooden chips better for the refining process and brings down the energy consumption (steam) of the process.

Beside the amount of solids in the process water and the temperature, also the pH - value, the amount of chloride and the chemical oxygen demand value were investigated.

Even though not worked out in detail, it can be assumed that the contamination grade of the washing water also has a significant impact on the efficiency of the washing and furthermore the life time of refiner plates. Especially the amount of chloride plays a very important factor here, because chloride directly acts upon the used steel of the unit parts and can cause for example corrosion.

In the following figures, the results of the investigations reached at the defined process points at different factories will be shown. It has to be mentioned that due to the small numbers of samples taken and the short investigation period, the results cannot be seen as representative and they are not able to give a full overview of a TMP plant. As said before in this work, only the results gained with Method II will be considered.

Figure 25 and Figure 26 show the differences between the ash content at the beginning and the end of the process at various plants. Added in this chart is the washing efficiency, generated from this data. Both figures show that between the entrance and the exit of the washing process, depending on the different plants, the ash content reduction varies.

As visible, the different efficiencies vary quite widely. This variety can be explained with the different quality of the wooden chips, the degree of contamination and distinguishing component parts. Overall it can be said that some factories have to improve the chip washing to reach a maximum washing efficiency.

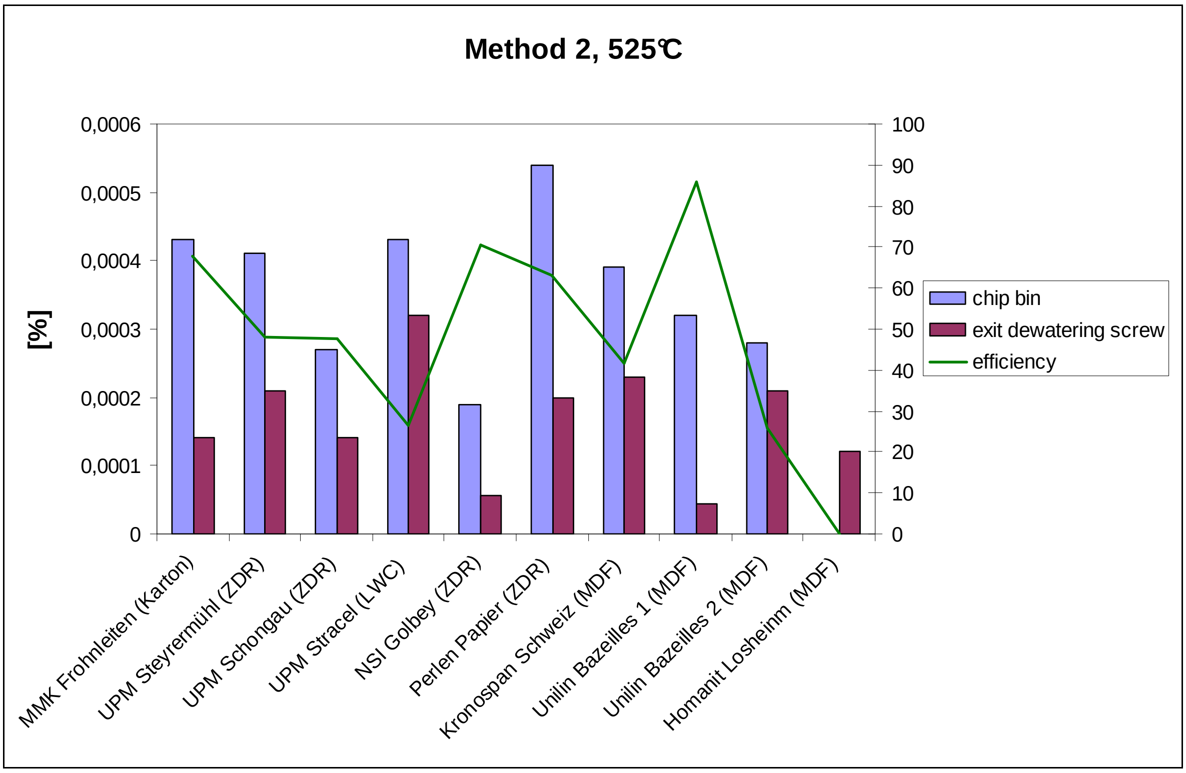

Figure 25: Ash content after combustion with 525 °C

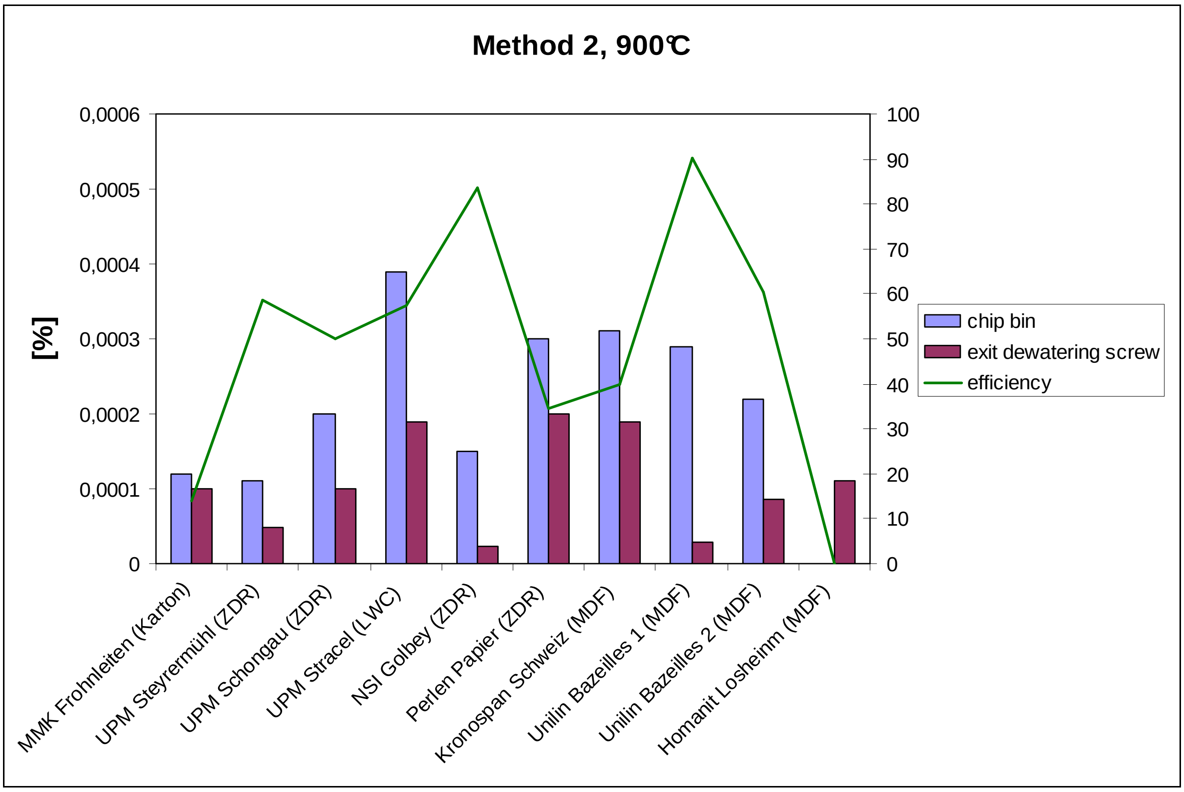

Figure 26: Ash content after combustion with 900 °C

Figure 27 shows the connection between the replacement intervals and the washing efficiency. As a higher ash content (900 °C; Method II) indicates a higher deterioration of the refiner plates [Mendrala 2008], the replacement intervals of the plates will be compared with the efficiencies investigated with Method II under 900 °C. The plates installed at UPM Steyrermühl show the longest durability, which leads to the assumption that the chip washing at Steyrermühl works quite well. At those plants where the minimal and maximal replacement intervals are congruent, the plates get replaced independent of wear around every six weeks. It is difficult to say in such cases whether the chip washing has an impact on the refiner plates. An exception in this chart is the factory Homanit Losheim, where no chip washing unit is installed. Here the plates have to be changed every three weeks.

The replacement intervals tabled in the figure justify the conclusion that by installing a chip washing unit in a process line, the lifetime of the refiner plates can definitely be prolonged [Mendrala 2008]. Even though the process at Homanit is a MDF process, it can be assumed that like in TMP processes the impact of the washing unit can be seen as similar.

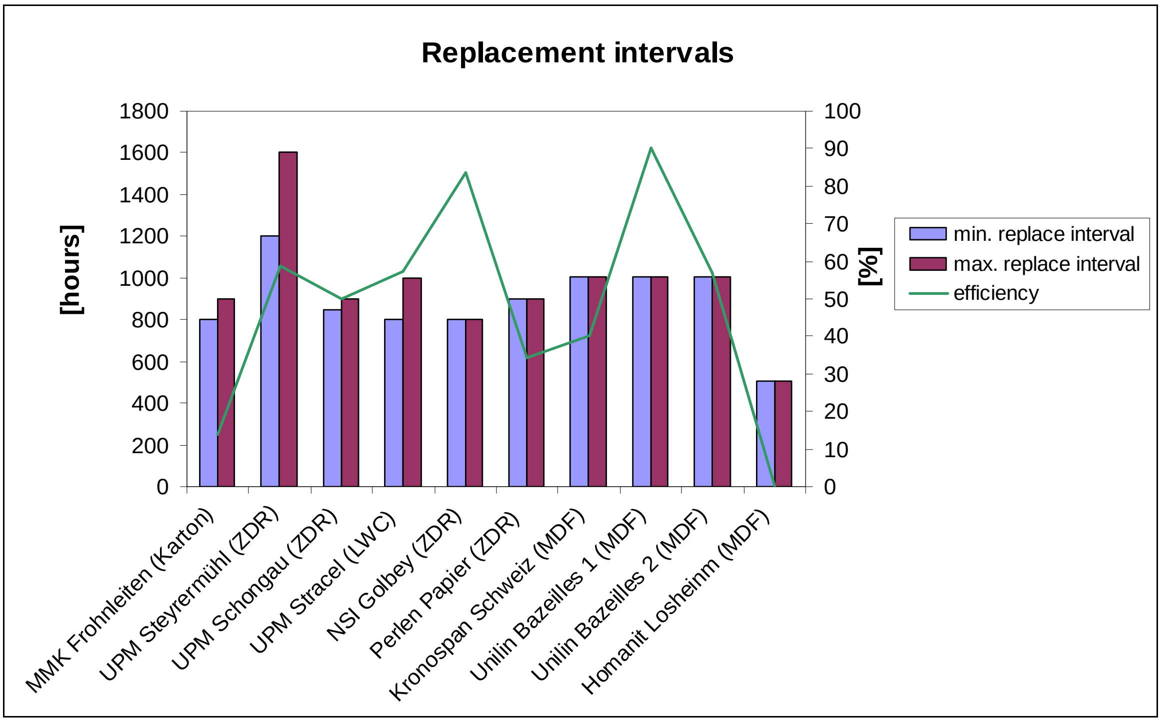

Figure 27: Comparison replacement intervals (refiner plates) and chip-washing efficiency

4.3 Theoretical Calculations

As wooden chips, sand, stones, metals and other contaminations show a different sinking and floating behaviour when they are mixed up with water, this behaviour has to be investigated before new concepts can be developed.

The criteria for a reasonable description of the sinking and floating features are:

- particle size
- sinking speed
- floating speed
- particle behaviour in a moving liquid medium
- centrifugal force

The calculations were conducted by reference to the invention of Hanaya Morimasa [Morimasa 1973] and the literature by Matthias Stieß and Siegfried Riepperger [Stieß, Riepperger, 2008].

Particle size

- Wooden chip

Sizes of an idealised wooden chip:

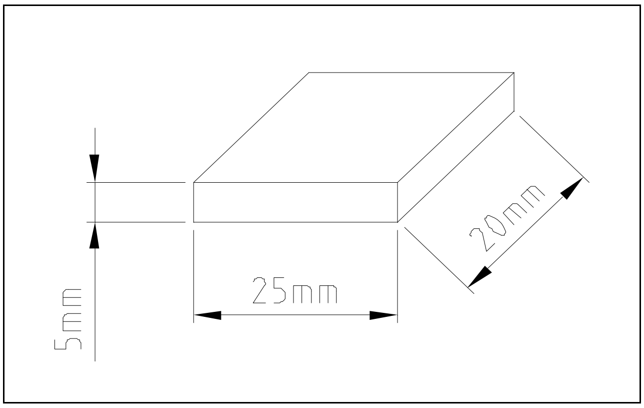

Figure 28: Size of a wooden chip

$V_{cuboid} = 2500 mm^3$

Average density of spruce in dry condition: $\rho_{solid} = 470\left[\frac{kg}{m^3}\right]$

The density of water can be assumed with: $\rho_{liquid} = 1000\left[\frac{kg}{m^3}\right]$

For a comparison between the floating speed of wood and the sinking speed of sand, the volume of the cuboid wooden chip has to be transferred into a spherical volume. This transfer works with the “equivalent diameter”.

The formula for the equivalent diameter reads as follows:

$$V_{cuboid} = V_{sphere,eq.}$$

$$V_{sphere} = \frac{d^3 \cdot \pi}{6} \Rightarrow d = \sqrt[3]{\frac{6 \cdot V_{sphere}}{\pi}}$$

With $V_{chuboid}$ inserted follows:

$$d_{sphere,eq} = \sqrt[3]{\frac{6 \cdot 2500}{\pi}} = 16.8[mm] = 0.0168[m]$$

Sinking and floating speed in an ideal static fluid

$$w_{Stokes} = \frac{\rho_{solid} - \rho_{liquid}}{18 \cdot \eta} \cdot g \cdot d^2$$

For water it is valid that $\eta = 1[Pas]$

$$w_{Stokes} = \frac{470 - 1000}{18} \cdot 9.81 \cdot 0.0168^2 = -0.0815\left[\frac{m}{s}\right]$$

This means that dry wood will float up with 0.0815 m/s.

According to [Morimasa 1973] sand with a particle size of 1 mm sinks with a sinking speed of 0.013 m/s. So the difference between the sinking and up floating speed between the particles is 0.0685 m/s.

Particle behaviour in a moving liquid medium under ideal laminar conditions

The particle size is calculated with the formula by Stokes [Stieß, Riepperger 2008] for laminar conditions, which describes the smallest size of a particle which would sink in a moving medium, against the floating direction:

$$d_{Stokes} = \sqrt{\frac{18 \cdot \eta \cdot x}{(\rho_P - \rho_F) \cdot g}}$$

With x being the floating speed of the liquid medium, in this case the medium is water. The floating speed of the liquid medium will be taken for a rough calculation with 1 m/s and 0.1 m/s

The average density of sand in dry condition can be taken with: $\rho_{solid} = 1500 \left[\frac{kg}{m^3} \right]$

From these values it follows that the size of particles that possibly sink under countercurrent conditions is:

$$d_{Stokes1} = \sqrt{\frac{18 \cdot 1 \cdot 1}{(1500 - 1000) \cdot 9{,}81}} = 0{,}06[m] = 6[cm]$$

$$d_{Stokes2} = \sqrt{\frac{18 \cdot 1 \cdot 0{,}1}{(1500 - 1000) \cdot 9{,}81}} = 0{,}019[m] = 1{,}9[cm]$$

Centrifugal force

The centrifugal force is important to know if it is planned to use rotating systems like centrifuges.

According to Stieß and Riepperger [Stieß, Riepperger 2008], the centrifugal force is generally calculated with this formula:

$$F = m \cdot r \cdot \omega^2$$

Exemplary for the different particles in the mixture, the force for grit, sand and chips is calculated. The particle surface for a sand and grit particle can be considered to be spherically for a rough estimation.

The speed of rotation was assumed with $n = 3000[rpm]$.

As n is defined right now, ω can be calculated with $\omega = 2 \cdot \pi \cdot n$.

It follows that $\omega = 314.16\left[\frac{rad}{s}\right]$.

The radius r to calculate the centrifugal force was taken with 0.1 m to visualize the different forces of the medias.

- ***Sand***

The diameter of one grain of sand was assumed with $d = 1[mm]$.

With the formula for the volume $V_{spheric} = \frac{1}{6} \cdot d^3 \cdot \pi$, the volume for one grain follows as:

$$V_{spheric,Sand} = \frac{1}{6} \cdot 0{,}001^3 \cdot \pi = 5.236 \cdot 10^{-10}\left[m^3\right].$$

The mass of one grain is calculated with the following formula:

$$m_{Sand} = \rho \cdot V = 1500 \cdot 5.236 \cdot 10^{-10} = 7.85 \cdot 10^{-7}[kg]$$

With this knowledge, the centrifugal force resumes in:

$$F_{Sand} = 7.85 \cdot 10^{-7} \cdot 0.1 \cdot 314.6^2 = 7.75 \cdot 10^{-3}[N]$$

- ***Grit***

The diameter of one grain of grit was assumed with $d = 5[mm]$.

Volume of one particle:

$$V_{spheric,Grit} = \frac{1}{6} \cdot 0.005^3 \cdot \pi = 6.5 \cdot 10^{-8} [m^3]$$

With a density for grit of $\rho = 1800 \left[\frac{kg}{m^3}\right]$, the mass of one grit particle is calculated as the following:

$$m_{Grit} = \rho \cdot V = 1800 \cdot 6.5 \cdot 10^{-8} = 1.17 \cdot 10^{-4} [kg]$$

With this knowledge, the force resumes in:

$$F_{Grit} = 1.17 \cdot 10^{-4} \cdot 0.1 \cdot 314.16^2 = 1.1547 [N]$$

- ***Wooden chips***

The volume of one wooden chip, together with the size and density, is also taken previously:

$$V = 0.02 \cdot 0.25 \cdot 0.005 = 2.5 \cdot 10^{-6} [m^3]$$

From this it follows that the mass of one chip is $m = 470 \cdot 2.5 \cdot 10^{-6} = 0.001175 [kg]$.

The value of the centrifugal force results to:

$$F_{Wood} = 0.001175 \cdot 0.1 \cdot 314.16^2 = 11.597 [N]$$

With this calculation it could be shown that the centrifugal force of wooden chips is very high compared to grit and sand.

4.4 Illustration of new washing concepts

After determining the above mentioned features of wooden chips in a liquid fluid, some technological solutions for new concepts could be excluded. It turned out that it is very difficult to separate the chips from sand with a wet washing system.

Systems like for example centrifuges and sedimentation tanks will not be considered, because of the reasons mentioned before and possible problems with asked mass flows per hour and too long dwelling times. Another problem is that centrifuges have quite high rotation speeds, which on the one hand raises the energy level and on the other hand when chips, sand and stones rotate with high speed in the centrifuge, the abrasion within will cause a higher maintenance effort and consequentially higher costs. The most effective way to clean the chips from fine sand particles would be to change the complete contaminated washing water once in the process. The amount of water needed in these systems is nearly constant, because all the washing water is recycled. One of the following concepts deals with the chip washer itself, the others deal with a newly designed chip washer and a solution for the water exchange.

According to that fact it can be assumed that the amount of impurities, which leave the washing process, are lower and the life time of the refiner plates could be raised.

In some concept designs, arrow streams are visible through the units, which express the feed stream (wooden chips, water) through the equipment.

4.4.1 Concept "spray"

The idea behind this system is to redesign the bottom inlet of the wash water into the chip washer. At the bottom of the washer, at the top of the valve section, a spray nozzle should be installed. The nozzle is circularly designed, closed at the lower end and the top is like a sieve, where the water sprays out. The circular design is necessary, because the nozzle can be installed in the washer without changing anything at the existing washer. Just the inlet flange and the pipe from the inlet to the washer need to be exchanged.

The bottom inlet should be modified so far that there is a calmed zone in the funnel part, where sunken contaminants can settle. In the actual system, the contaminants get partly awhirl, because the wash water inlet is located right over the scrap valve. With the new design this phenomenon can be excluded, but the necessary upward flow of chips that would possibly sink can be guaranteed. The exact location up to where the nozzle tube projects in the washer in order to allow only a few chips to be sluiced out with contaminants has to be found by trials or simulations.

A second benefit is that the flow rate of the up flow can be handled more precisely. Because of the nozzle geometry it is no longer possible to run the process with more water entering from the bottom inlet than from the top inlet.

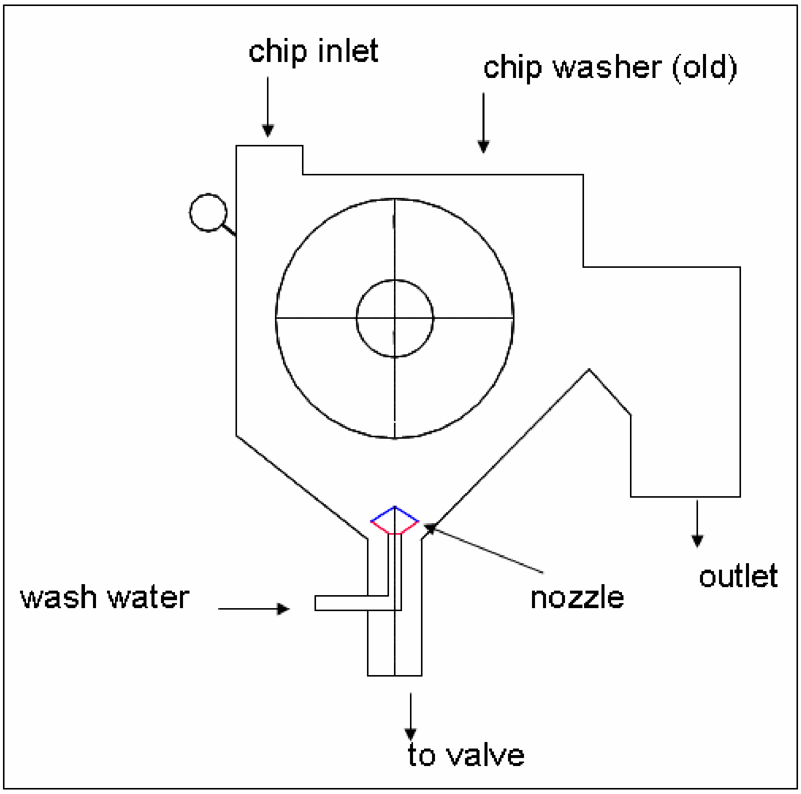

Figure 29: Illustration of the concept "spray"

4.4.2 Concept "cyclone"

Referring to the Kostiainen invention [Kostiainen 1977], this system consists of the washer that would be nearly the same as in the invention and a redesigned outlet channel. The wash water inlet at the bottom of the washer is equipped with the new spray design mentioned in the last subchapter. In the outlet channel, the mixture of water, chips and sand flows over a sieve tunnel where water and sand are eliminated from the process. The purpose of this sieve in the outlet channel is to divide the pre-cleaned chips from the contaminated water. The angle of dip of the outlet channel has to be designed in a way that guarantees that the speed of the chips is so high that they skid over the sieve and most of the water can be eliminated. This angle can only be tested under real conditions, because it depends on the chip behaviour under these conditions. In the scope of the thesis such a testsetup would be too elaborate. After the sieve, the chips fall into a pipe where fresh water is added and are transported forward into the chip pump sump. With this system, the ratio of sand particles, which that arrive at the dewatering screw can perhaps be lowered by changing the washing water once.

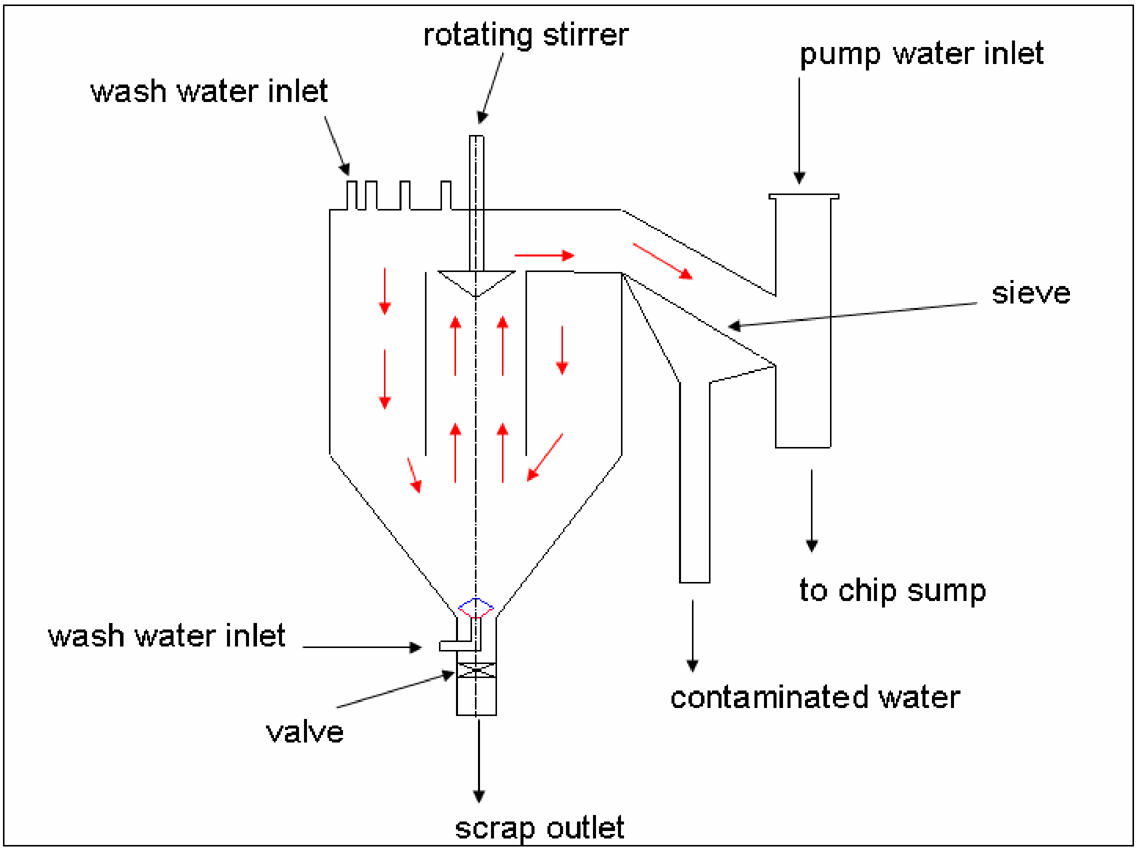

Figure 30: Illustration of the concept "cyclone"

4.4.3 Concept "feeder screw"

The new concept is installed instead of the actual feeder screw. The chips coming from the chip bin are usually transported forward to the washer by a normal feeder screw. In the new system, the chips are brought in contact with washing water and in the next step the water is removed, before the chips enter the washer. This whole process happens during the transport between bin and washer. Therefore the housing of the feeder screw has a special design. On the top there are wash water inlets where the water is pumped into the screw. It must be excluded that water can ascend back in the chip bin, so the exact location where the water inlets are situated has to be evaluated. For an optimized result trials would be necessary to find the best location for the water inlets. The upper part of the screw housing is closed; the lower part is manufactured in sieve form. The first benefit of this system is that it should be possible to wash out sand and small particles with the sieve before the chips enter the washer. The second benefit would be that with the friction of the chips during the transport in the screw and in combination with the water on the chips, contaminations adhering to the chip surface can be better removed by the washing water added in the chip washer.

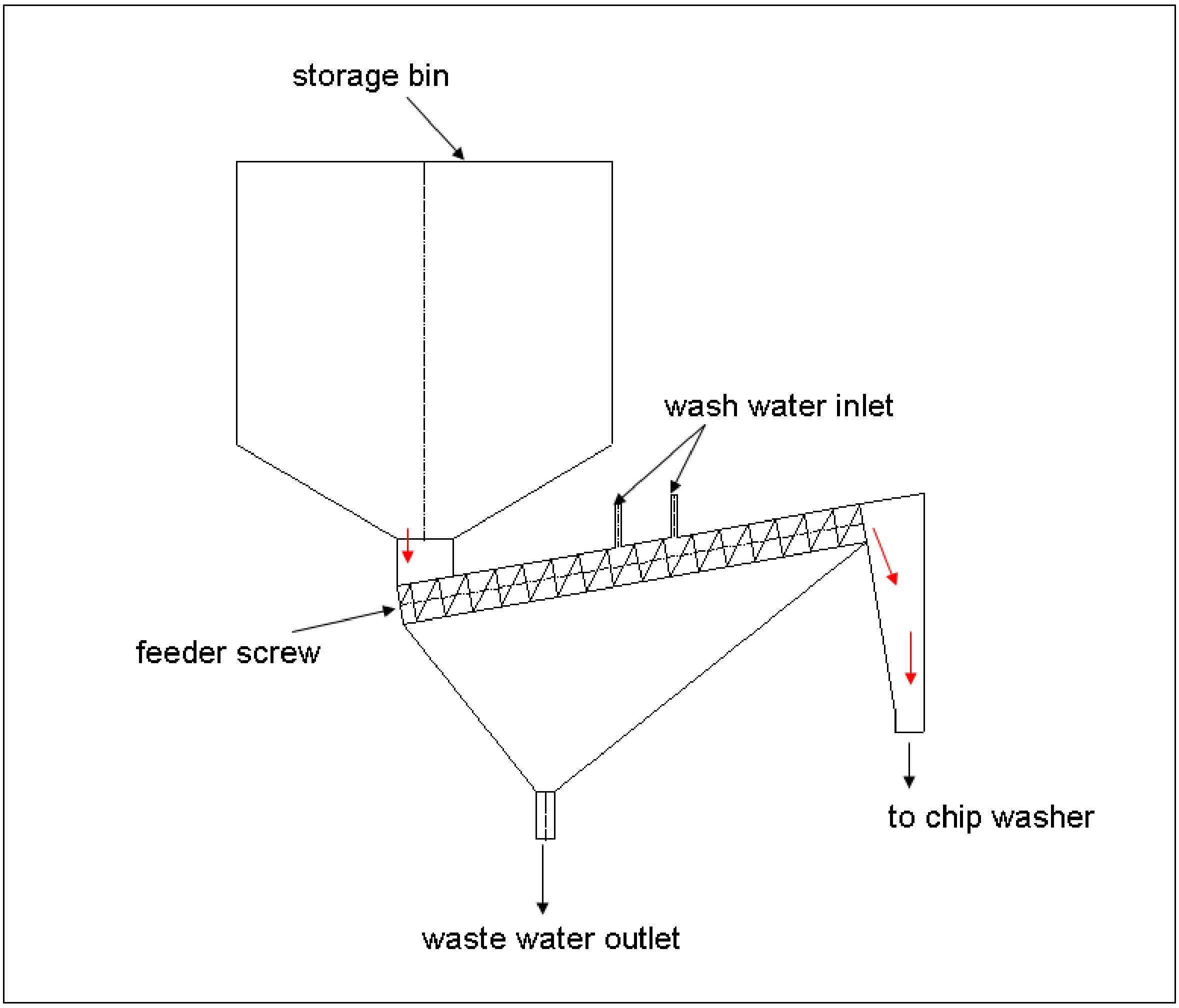

Figure 31: Illustration of the concept "feeder screw", front view

The structure of the sieve housing and the lower part of the concept where the contaminated water exits the process, as well as a side view are pictured in Figure 33

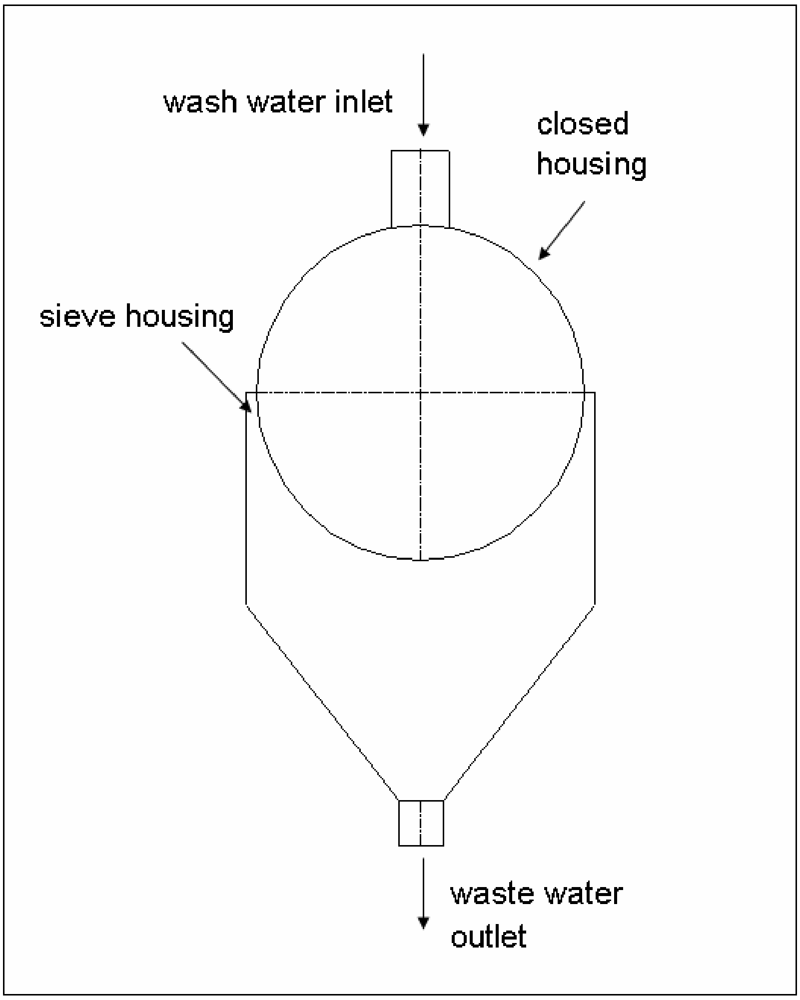

Figure 32: Concept "feeder screw", side view

4.4.4 Concept "bow screen"

As visible in Figure 33, a bow screen is installed after the chip washer, before the chip pump sump. The chips slip down along the surface of the bow screen in the direction of the pump sump. Through sieve holes, the wastewater is divided from the chips. After the bow screen, the chips are flushed with fresh water and enter the pump sump. With the bow screen it is possible to change the total amount of wash water, and by using new water after the screen the contamination of sand and small particles in the wash water that enter the drainer screw can be reduced. To install this system, the old chip washer can be used and instead of directly moving the chips further to the chip pump sump, the bow screen is installed.

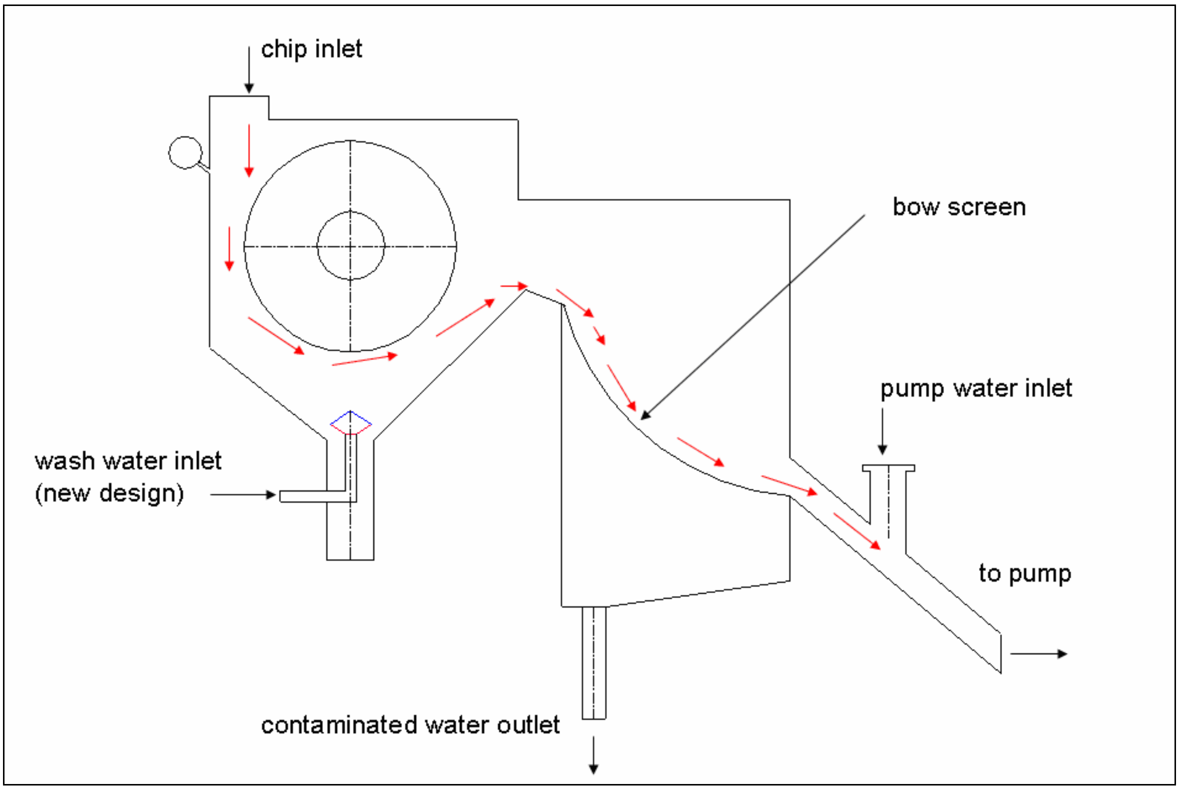

Figure 33: Illustration of the concept "bow screen", front view

As the chip washer and the bow screen are rectangular parts but the wash water is added in a pipe, the short crosspiece between the bow screen housing and the pump water inlet has to be mounted in the way shown in Figure 33. The biggest problem with this design is that on the one hand, the slope angle of the so called slide must be high enough to guarantee that the chips slide down. On the other hand, the point at the end of the slide where it is welded together with the pump water inlet is a bottleneck. Here the coming down chips could cause plugging, which has to be avoided under all circumstances. Therefore, even if it is possible to change the total amount of contaminated water, this should not be done. The reason for this is very simple. A high water to chip ratio at that stage of the process improves the mobility of the chips. Instead of sliding with different velocities, chips would be washed down the slide and the danger of plugging is minimized by this constant water/ chip stream. A possible way to limit the amount of water that gets separated at the bow screen is to downsize the sieve holes until the desired effect is achieved.

Figure 34 illustrates the top view of the transition piece between the bow screen housing and the pump water inlet:

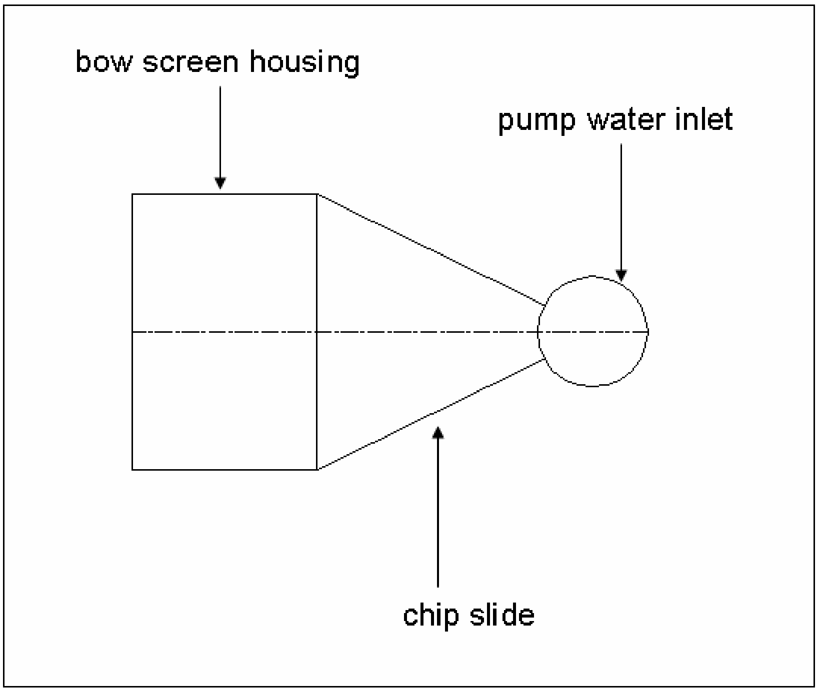

Figure 34: Concept "bow screen", top view of the outlet channel

4.4.5 Concept "rotating sieve"

After the feeder screw the chips are flushed into a vertical pipe by the washing water, in which sheet metals in form of triangles are installed. On the one hand this forces the chips to follow a tortuous path, and on the other hand it removes contaminants adhering to the chips. This inlet design has two advantages:

The first one is that the contact surface between the chips is very high and with the friction of the chips between each other and with the surfaces of the washer, the contaminations can be removed from the chips effectively. The second advantage is a prolonged retention time for this effect. When chips flow downwards, they enter a sedimentation zone where the heavy particles fall out. The chip inlet is situated higher than the outlet, so water flows because of the gravitational force over a weir and a sieve into a rotating drum. The drum is also manufactured as a sieve. With these two sieves it should be guaranteed that there is no contaminated water left when the chips leave the drum. After the sieve the chips are flushed with clean water and moved forward in the process. The design of the transition piece between the drum sieve housing and the pump water inlet has to be chosen carefully to guarantee an optimized result. It is imaginable to design it like the outlet channel of the concept "bow screen" under the restriction of keeping an amount of not cleaned water in the process.

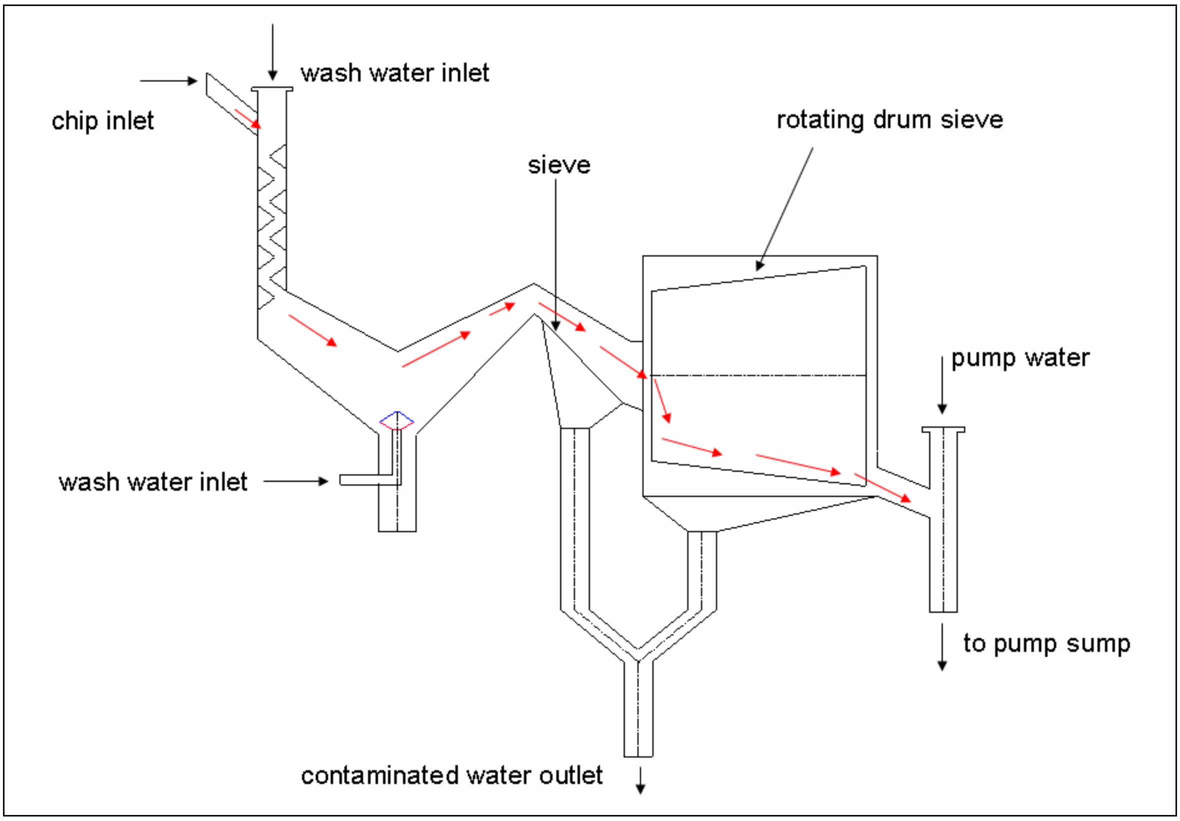

Figure 35: Illustration of the concept "rotating sieve"

4.4.6 Concept "rotating drum sieve with changed feeder screw"

This concept combines several previously mentioned parts with a new idea. By taking a view on the inlet, the currently in use feeder screw is replaced by an angular installed screw. At certain points of the screw, wash water will be added to the process. The advantage of this screw design is that the risk of water descending back to the chip bin can be minimized, but the advantages such as the friction of the chips are preserved. The chips are moved downwards by the screw and enter the sedimentation zone, which consist of a cylindrical body shell tank with a bottom wash water inlet to prevent heavier chips from sinking. Therefore a nozzle like in the concept “spray” is installed at the bottom where still sinking heavy material gets sluiced out. As the outlet of the tank is placed lower than the position of the water inlet, the chip water mixture would flow, because of the gravity over a weir and a first sieve plate.

The function of the sieve plate is to separate a certain amount of water from the chips and by doing so to reduce the workload of the rotating drum sieve. It has to be mentioned here that the problem of designing the connection of the drum sieve outlet and the water inlet is the same as in the concept “rotating sieve”, as the two concepts are very similar at that point of the process.

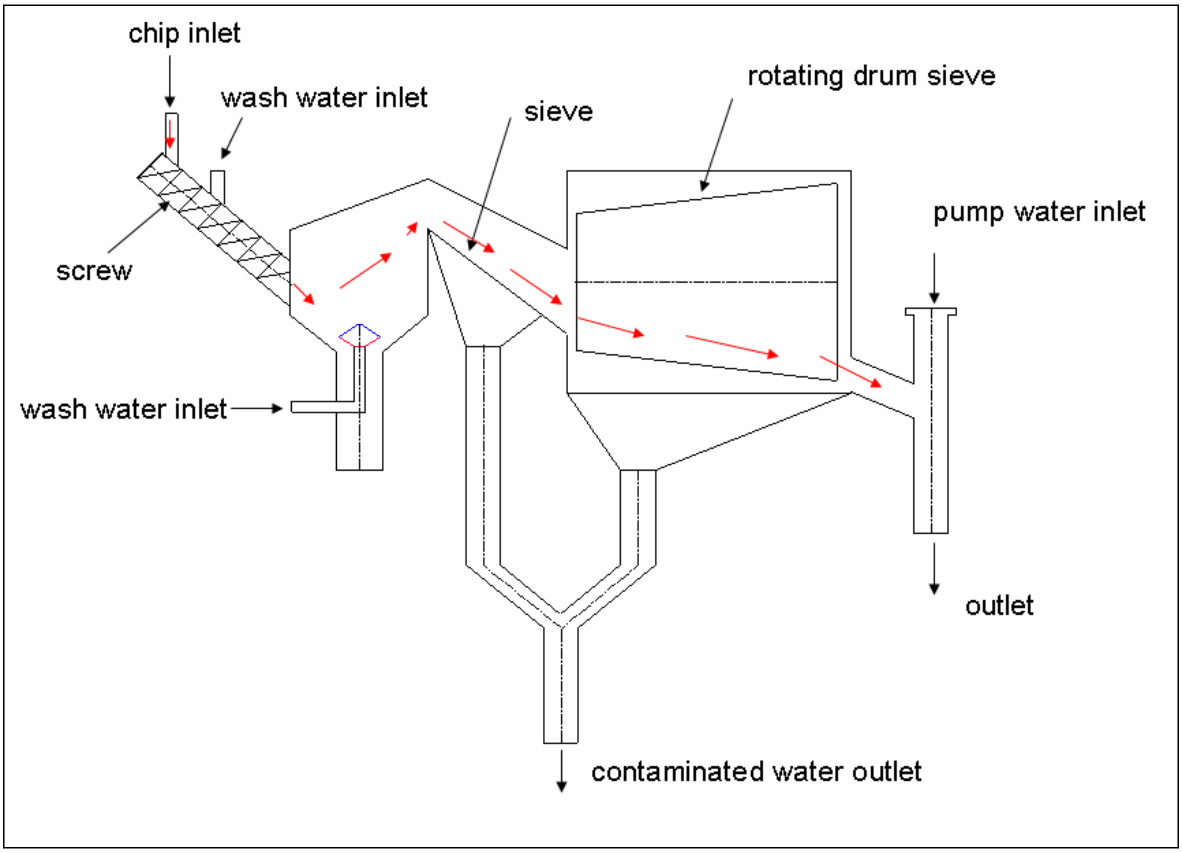

Figure 36: Illustration of the concept “rotating drum sieve with changed feeder screw“

4.4.7 Concept "drum sieve wood yard"

Another idea for a new system would be to locate the washing on the wood yard, before the chips are stored in the chip bin. Usually at already existing process lines, the free space outside is larger which makes it a lot easier to install a new washing system. But it must be kept in mind that a unit located outdoors is not applicable in all geographic regions. As the washing liquid is water, precautions have to be taken in cold regions to prevent the water from freezing.

If for example a hall has to be built for the washing unit, because the temperatures are very low in winter to guarantee that the water would not freeze, this system becomes unattractive. The process consists of a conveyor belt feeder coming from the chip fractioning, which feeds the mixing tank with raw material. At the top of the mixing tank, the wash water is added. At its top end, the rotating drum sieve has vents to allow the mixture to flow into the sieve drum. The perforated shell of the rotating sieve allows the water to leave the process, while the chips stay in it. The sieve holes have to be dimensioned in such a way that sand and bigger particles like stones can exit the process, but the chips are held back. In the drum, metal sheets are welded in (90° angle to the sieve housing) to increase the retention time of the chips in the drum and create friction forces. At the bottom end of the sieve drum, the whole water and the contaminations should be eliminated and cleaned chips fall on the conveyor belt to the chip bin. The wash water is recycled in a recycling process and re-added to the process at the top of the mixing tank, where the chips enter the process.

The reasons for installing this concept on the wood yard may be the following:

- It could be a prewash before the already installed washing unit to improve the washing efficiency.
- At production sites where actually no chip-washing unit is installed and the weather conditions are acceptable, it would be a quite easy way to upgrade the mechanical pulping or fibreboard process with a washing unit that consists of a few big parts. Also the possibility to install it outside existing buildings could be positive.
- Instead of having a chip washer, a chip pump and a drainer screw, this component unites all these functionalities in one big unit.

The concept is presented in the following Figure 37:

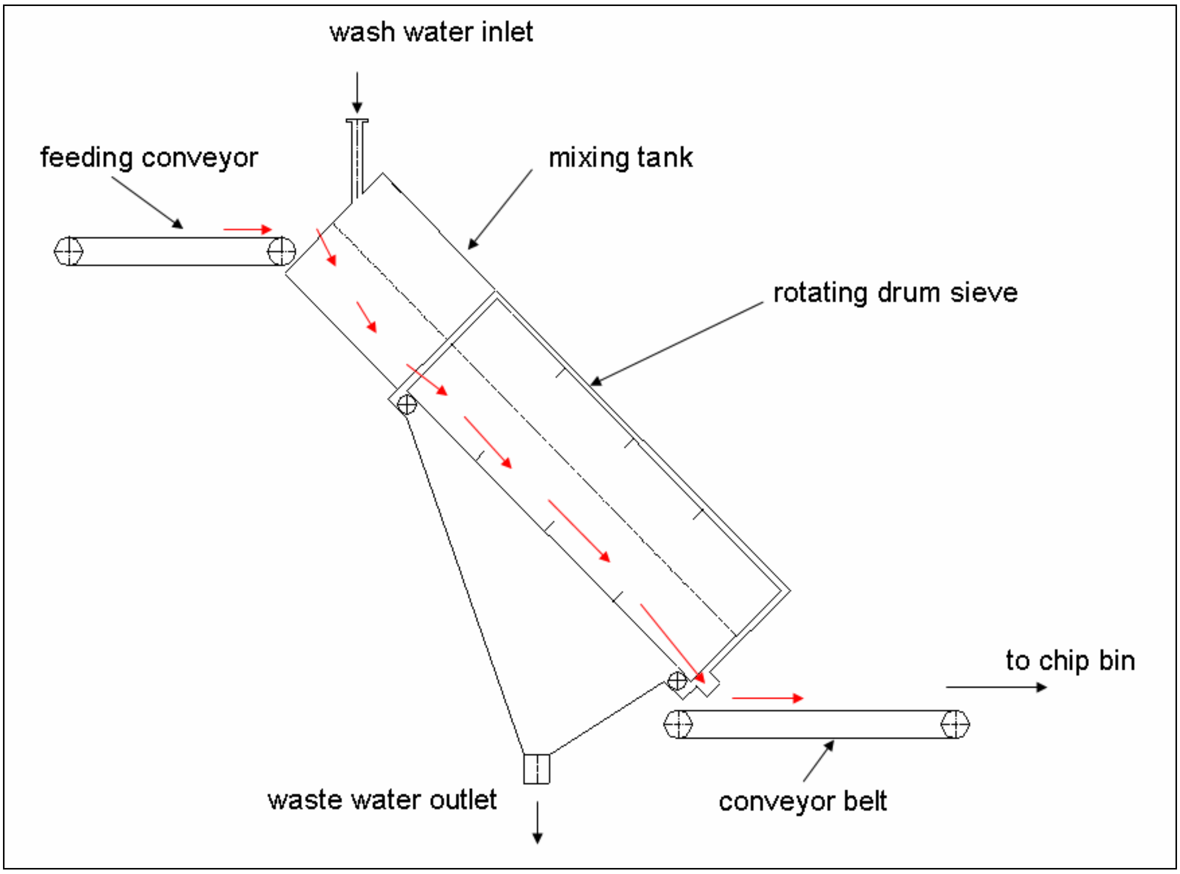

Figure 37: Illustration of the concept "drum sieve woodyard"

4.4.8 Concept "nozzle sieve"

This concept is based on already existing separation concepts in the mining industry. The first part of this concept contains a rectangular sedimentation tank. In this sedimentation tank, heavy material sinks down and will be eliminated from the process.

The chip- and the wash water inlet are located at the top. The chip and water mixture flows down a metal sheet and has to change direction. Then the chips float up again and through a connection tunnel to the sieve. The sieve is divided into for example 3 sections. The chips enter the first section and because of the sieve plates, the water is eliminated. At the end of the first section, only chips are present in the process. At that point, the chips are flushed with washing water and transported further downwards. The sections two and three work on the same principle. The contaminated water is recycled and re-added to the circle.

Depending on the washing efficiency which could be reached with this system, an additional washing stage could be added or removed. At the end of the last section, the chips fall down a vertical tunnel and onto a conveyor belt, which transports them to a collection point installed right before the plug screw.

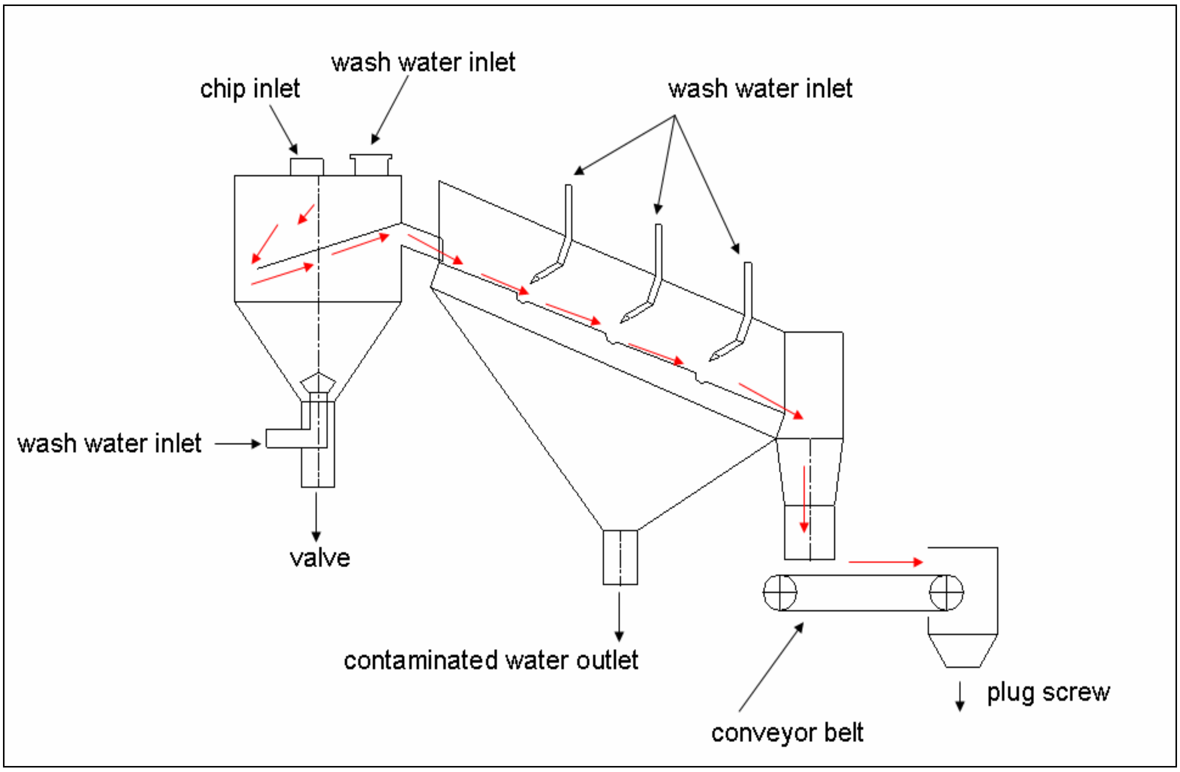

Figure 38: Illustration of the concept "nozzle sieve"

5 Selection of a newly designed chip-washing unit

In the previous chapter, several new chip-washing designs were presented. These designs were discussed in an expert panel to find out their respective strengths and weaknesses. In this panel, one design was selected and further elaborated in more detail.
The selected design is the concept "spray", not in its original version, but this concept was expanded during the discussion in the panel. As shown in the previous chapter, the original new concept only proposed a bottom wash water inlet. But now the idea is to keep the body of the existing chip washer and to re-design the chip inlet, the bottom wash water inlet and the chip/ water mixture outlet of the chip washer. All these components were worked out in detail, but since the actual concept idea is based on the presented concept "spray", no additional 2-D drawings were created. The new designs are directly visualized in 3-D models. The selection criteria which were defined at the beginning of the development process and in the panel, detailed advantages, a 3-D model of the assorted concept and a rough cost estimate are discussed in this chapter.

5.1 Selection criteria

There are several selection criteria which lead to the decision for a new concept. It is quite difficult to judge which criterion weighs more than others. Selection criteria are the site location, the way the single components are mounted in a process line, the requirements to the material when it enters the refining stage and further more. At the beginning of the concept development, a functional specification document was worked out (Chapter 5.1).

The main criteria that the new development has to fulfil are listed as follows:

- Performance improvement of the washing process
- Better and earlier sand separation
- Maintenance effort should be low
- Concept should fit in existing washing lines
- Concept should be installable in all common process sizes

- Reduction of water consumption
- Reduced energy consumption

These points were the major cornerstones for deciding which concept should be worked out in detail. In the expert panel in charge of selection one concept from all the suggestions, the question came up which issue could be the most important for a customer. This product has to be sold to customers who either have an Andritz system or a system built by a competitor or maybe no chip-washing system installed. On the one hand this is very effective and on the other hand it provides the most customer friendly arguments for an upgrade of their existing chip-washing unit, or a change from a unit that was built by a competitor of an Andritz unit.

For customers, usually the following issues are important:

- Installation possibility in every existing chip washer system.
- Least effort for the customer, while the new system is mounted. This can be carried out for example at a planned maintenance stop of the process line.
- If the customer is not satisfied with the new system, there should be the possibility to rebuild it back to the original state at any time.
- The efficiency of the process is raised and this will have positive effects on the whole site performance.
- The price of the new system should be in the range of the old system, or maybe the efficiency can be increased to a level where costs in other parts of the process can be saved.

It has to be mentioned that the concept “spray” with its extensions, which will be discussed in the following chapter, has turned out to be the most promising potential new-design, but for a better visualization and understanding of why this concept was chosen, the criteria and all new concepts are shown in the following table. It has to be pointed out, that all decisions were taken on the basis of theoretical knowledge gained during this work and assumptions made during the development process.

Concept	Performance improvement	Sand separation	Maintenance effort	Mounting effort	Fitting in existing lines	Process reliability	Price forecast	Customer-friendly*
Spray	Medium	low	low	low	yes	high	cheap	very
Spray (expanded)	High	high	low	medium	yes	high	relatively cheap	very
Cyclone	High	high	medium	very high	no	medium	expensive	not really
Feeder screw	High	high	medium	very high	no	high	expensive	not really
Bow screen	High	high	medium	very high	no	high	expensive	not really
Rotating sieve	high	high	medium	very high	no	medium	expensive	not really
Drum sieve, chg. feeder screw	high	high	medium	very high	no	medium	expensive	not really
Drum sieve wdyd.	high	high	medium	very high	perhaps	high	expensive	not really
Nozzle sieve	high	high	medium	very high	no	high	expensive	not really

Table 9: Selection criteria/ process of new concepts

**Remark of the author: The criterion "customer friendly" describes a customer's effort of installing the concept and can be seen as a conclusion of all the other criteria expressed in the table. If a concept is very customer–friendly, the chances are very high that it can be sold to him and installed at his site location.*

5.2 Advantages of the expanded concept "spray"

As depicted in Table 9, the concept "spray" and the "expanded concept spray" show a very good match to the criteria. As the sand separation and performance improvement is better for the expanded concept spray, this concept was chosen to be elaborated in more detail. Another advantage is that-depending on the customers' desires-, all three parts (Inlet, Outlet and Bottom Inlet) can be upgraded, or just single pieces. A higher installation effort because of the design and a resulting higher price level are subordinate in comparison with the achieved improvement. Concluding, the most important advantages of the concept are:

- The new inlet design supports the washing process by prolonging the washing time and supporting the separation of chips and adhering contaminants.
- In the washer, the separation of water and heavy material would be improved.
- Sand and small particle separation is included in the system. With all small contaminants separated in the chip washer, all downstream process stages profit. The reason for this is mainly that the wear of the components is reduced. This point is realized with the new outlet design.
- With the possibility to separate the sand from the washing water the work load for the twin screw drainer will be reduced.
- The inconvenience factors for the customers are kept very low and if the customer is for whatever reasons not satisfied with the new system, it can be dismantled back to the original system.
- The price for the washer itself would probably just be marginally higher than it is today, as the new parts are simple to produce and the production effort can be seen as not quite increasing.
- As there are no additional rotating parts in the system, the energy need of the washer is the same as in the existing system. Additionally pumps, if needed do not belong to the energy need of the washer itself.
- Compared to the state of the art, this system would be unique in the industry.

The detailed advantages of the newly designed inlet, outlet and bottom inlet will be discussed in the following chapter, because it is easier to describe the advantages by directly referring to the 3-D models.

5.3 3-D Models

As part of this thesis, several 3-D models were created to visualize the developments. At this point it will be noted that the assembly drawing of the existing chip washer was conducted in a subproject, which was partly outsourced and looked after by Andritz internal personal, while further development parts were created directly by the author.

5.3.1 Chip washer assembly

During the evaluation it was discovered that no existing 3-D chip washer models existed within the company. As it could be important to have these models in the future, it was decided to create one. The existing HE 3000 was chosen to be modeled, as the install base of this chip washer size is probably very high.

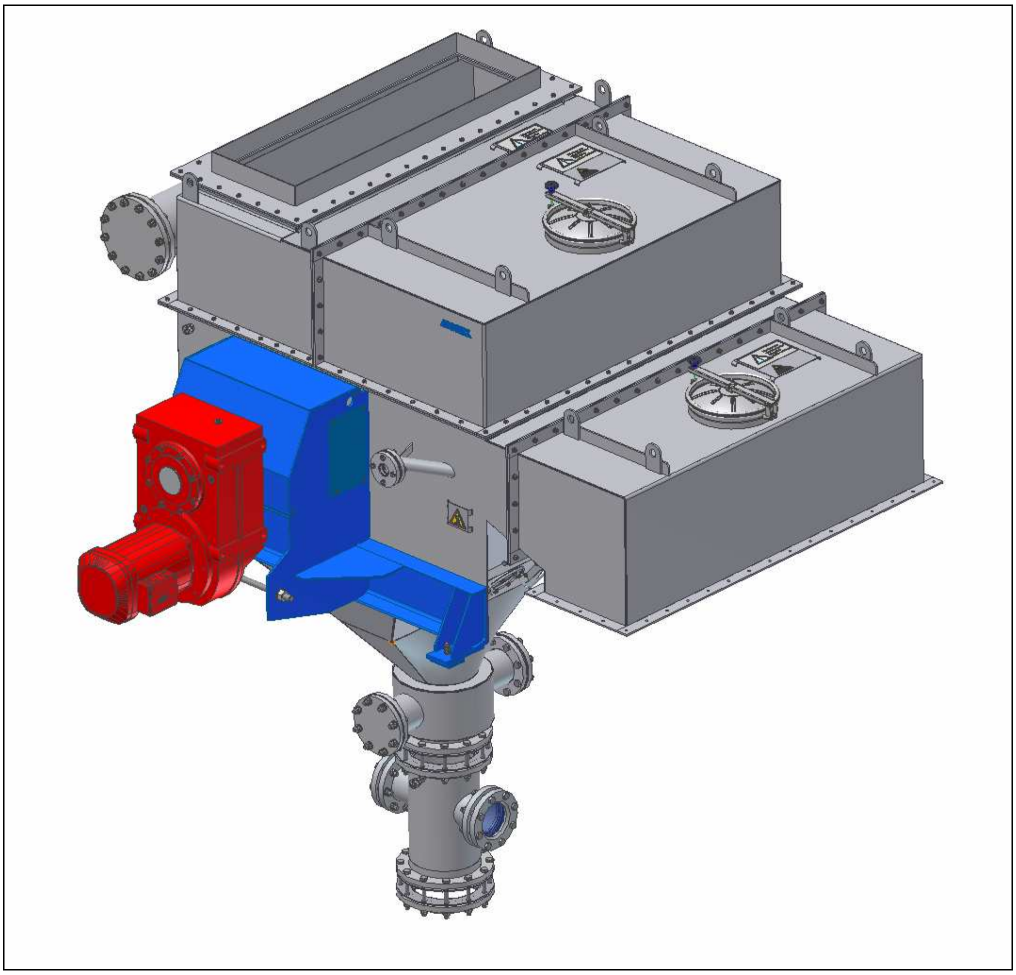

Figure 39: Assembly drawing of the HE 3000

To gain an insight into the chip washer, a cutaway view was created. This view gives a good impression of the functionality of a chip washer. The sluice arrangement under the bottom wash water inlet is just indicated, as this arrangement is delivered by a sub supplier and not manufactured by Andritz. For an explanation of the washing process in the chip washer see Chapter 2.2.2.

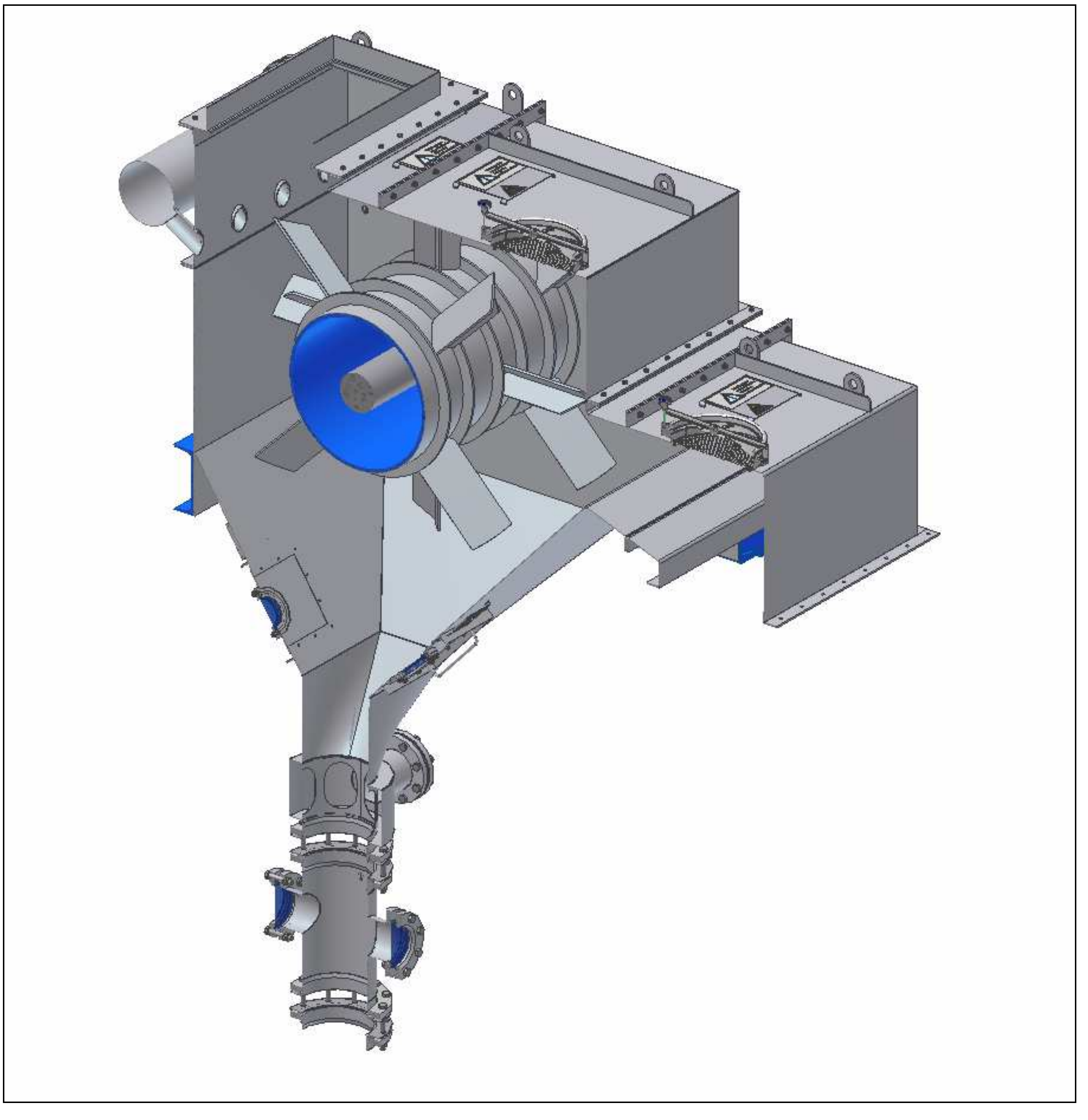

Figure 40: Cutaway view of the HE 3000

5.3.2 Assembly with new concepts

In Figure 41 a cutaway view of the previously shown assembly drawing was created, where all the new concepts are fitted to the generated 3D model to visualize the functionality of the new concepts. A detailed discussion of the new concepts (Inlet, Outlet, Bottom inlet) will be presented in the following subchapters.

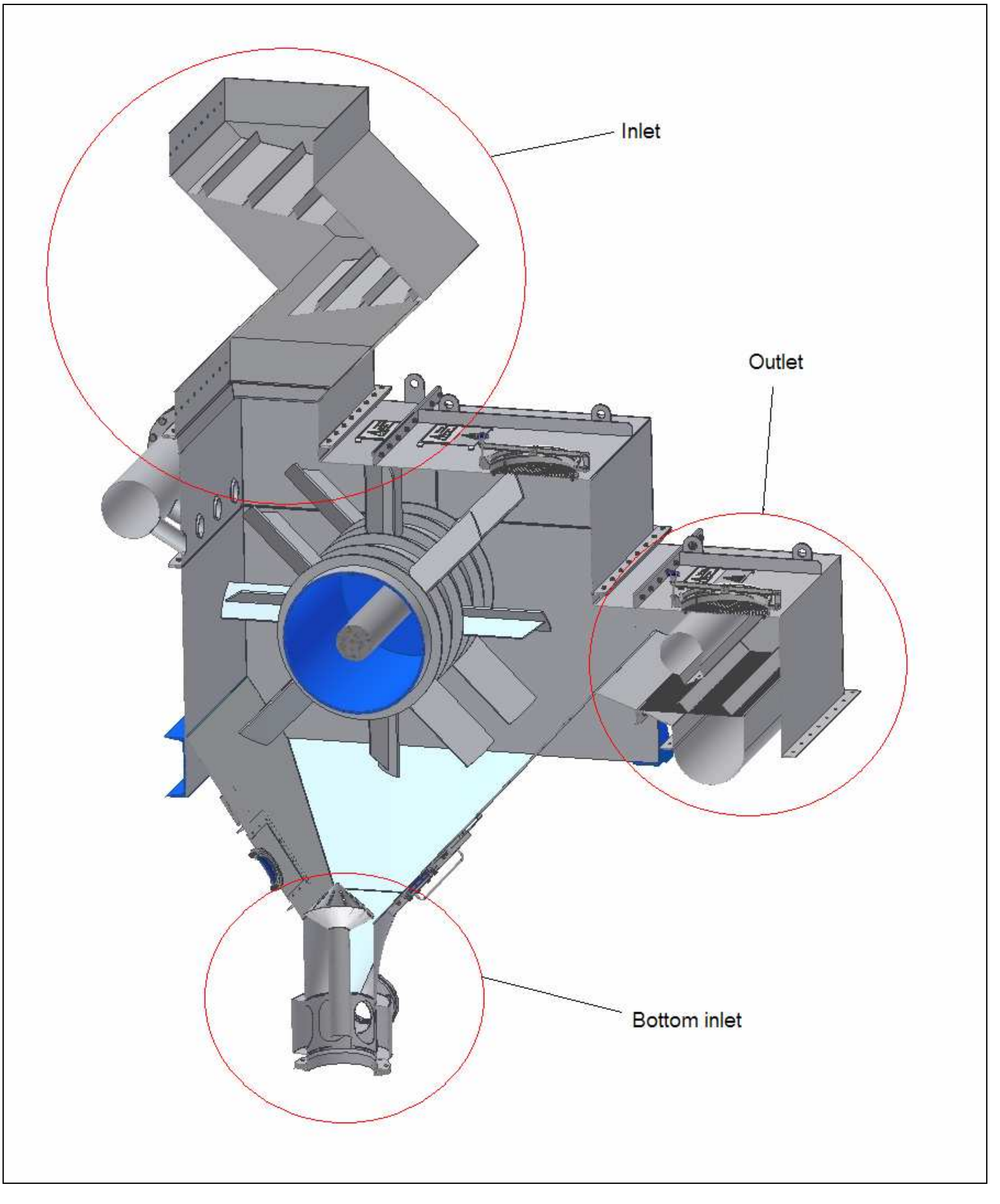

Figure 41: HE 3000 with new concepts

5.3.3 Inlet

Depending to the mounting situation at the site location, the inlet channel through which the chips coming from the feeder screw fall into the chip washer can look very different. The similarity at most of the sites is that the inlet channel is a direct vertical tube from the end of the screw to the washer. In the existing systems as mentioned before, the first contact of the chips with the washing water happens in the washer. Marked in red, picture 1 shows the chip inlet channel. The picture shows a mounting situation how it is actually in use in different process locations. The new chip inlet is designed to use this space for an earlier contact of the chips with the washing water and going along with this an earlier beginning of the washing.

Picture 1: Installed chip washer with inlet channel [Andritz internal]

Based on the requirements defined in the previous chapters, the solution for the new inlet design is shown in Figure 42:

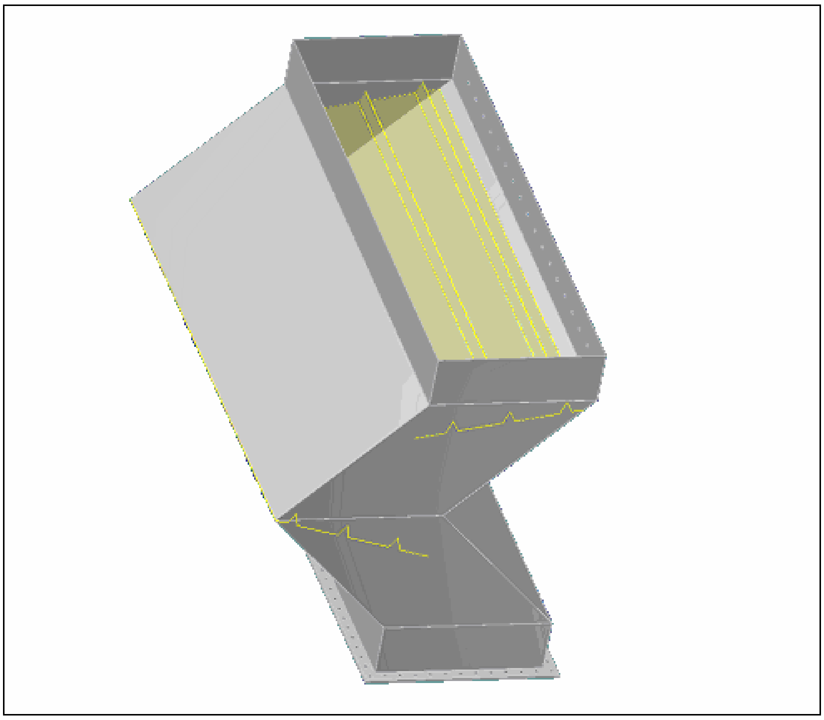

Figure 42: New inlet channel design

Instead of having a vertical channel, this design is constructed as two channels welded together under a certain angle. The biggest advantage of designing the new channel in this way is that the space needed for this system is only slightly larger than for a normal vertical inlet channel. The sizes of the channel are the same as the chip washer sizes, so the channel can be mounted directly on the existing inlet. Depending on the distance from the feeder screw outlet to the chip washer inlet, the angle can be varied. The only point of restriction is that the angle between the upper and the lower part has to be big enough to guarantee a constant downward flow of the chips. Two metal-sheets (marked in yellow) with small weirs are welded into the channel. The length of the sheets has to be chosen in such a way that the time, which the chips need to pass over the sheets, is as long as possible, but the danger of plugging has to be avoided. Also the angle from the sheets to the channel is modifiable. As all these parts are variable, the optimized dwell time for a pre-chip-cleaning can be found in trials.

The washing water is added at the top of the channel to flush the chips down into the washer. By the planned location of the inlet nozzles which covers the whole long side of

the channel (as visible in the figure), it is secured that the incoming chips have to float through the channel. There is also the possibility to add the washing water just at the top of the channel and to close the nozzles in the washer. Another version would be to leave the nozzles in the washer opened and thereby generate two points of water input. These options should be tested at a pilot process. Also the optimal amount of water feed for the best results should be a part of the investigations.
As the wooden chips have to float over the metal sheets with the weirs, the contaminants, which stick on the chips, should be removed. So the sedimentation of heavy material and the chip cleaning process that happens afterwards is facilitated.

5.3.4 Outlet

As the possibilities to eliminate small particles are very limited in the actual process, this option was generated by the new outlet design. Presently, sand and small particles are washed out with an optionally installed hydro cyclone, or at the end of the process in the twin dewatering screw with the washing water. According to Andritz personnel both systems, either the cyclone or the dewatering screw do not work properly to separate small particles from the chips. The reason why there are problems with the cyclone were not worked out in detail in this thesis, but an explanation is that the mass flow is simply too high for a proper separation achievement. As the primary function of the dewatering screw is to separate washing water from the chips with a reduced rotation speed, it could be that small particles like sand, dust and others suspended in the washing water begin to stick on the chips when they get lifted out of the water by the screw. It is for sure that the screw will eliminate a certain amount of small particles, but the grade of reduction is likely to be low. The main idea of the new outlet is to change the whole amount of washing water or at least reduce the amount small particles with contaminated water after the chip washer, before the chips enter an optionally installed hydro cyclone and later the dewatering screw. The real reduction potential can only be found out in trials, because parameters like the effective water level above the outlet weir are unknown and can only be assumed.
Before the creation of the drawings started, calculations were conducted to verify if it is generally possible to remove the amount of washing water which is necessary to run the process. Therefore these calculations only serve as a reference value to check if the

velocities in the pipes that transport the dirt away from the outlet can theoretically be provided by a pump.

Theoretical calculations

The calculations were conducted for the HE 3000, as it is a very commonly used size and all the designs were made in reference to this chip washer size. The following facts are already known from the process:

Amount of bone dry chips transportable through the chip washer:

$$Inlet_{max} = 39\left[\frac{t}{h}\right]$$

With a consistency of the mixture assumed with 5% chip concentration and 95% water, the total mass stream through the washer can be calculated to:

$$Mixture_{max} = 780\left[\frac{t}{h}\right]$$

Under the assumptions mentioned above, the amount of water in the mixture is 741 t/h.

As the function of the sieve holes is to separate water and fine particles from the chips, the holes must be dimensioned in a way that the chips are held back, but a maximum of water can pass through the holes. To get a feeling for whether it is possible to remove all the contaminated water out of the system, the diameter of one hole was assumed with 9 mm. This size could also be used in a real system. The available sieve area is rectangular with a probable dimension of 0.94668 m^2. This size of the sieve area guarantees a gap that is wide enough to prevent plugging in the connection between outlet and pump sump.

From empirical values it is known that the effective sieve area can be calculated as follows:

$$A_{eff} = A_{total} \cdot 0.8 = 0.94668 \cdot 0.8 = 0.757344\left[m^2\right]$$

With the calculated area and the already known amount of water, the flow speed through the sieve holes is:

$$v_{sievehole} = \frac{741\left[\frac{m^3}{h}\right]}{0.757344\left[m^2\right]} = 978.42\left[\frac{m}{h}\right] = 0.2718\left[\frac{m}{s}\right]$$

An assumption had to be made, how high the water level of the washing water leaving the chip washer and entering the outlet channel could be. By talking to Andritz personnel it came out, that in the present washer design the washing water flowing through the outlet channel doesn’t need the whole diameter of the channel. The area where water flows through can be assumed with about 0.53508 m^2, which is about half the diameter of the outlet channel. This area is necessary for a rough calculation of the flow speed of the water in the present channel:

$$v_{outlet} = \frac{741\left[\frac{m^3}{h}\right]}{0.53508\left[m^2\right]} = 1384.84\left[\frac{m}{h}\right] = 0.3847\left[\frac{m}{s}\right]$$

As visible in the calculations above, the chip/ water outlet entering velocity is higher than the velocity of the water through the sieve holes. Therefore it is necessary to increase the velocity of the water going through the holes to sluice out as much water as possible. This could be reached by an increase of the sieve-hole diameters, or as it is a process with a constant water flow, a pump mounted at the outlet channel could create a suction that forces the water to speed up. The suction has to be high enough to speed up the water going through the sieve holes, but low enough to prevent the chips from sticking to the sieve plate. A very important point here is, that it has to be guaranteed, that the pump is prevented from dry running conditions and going along with it, damages. The water outlet channel visible in Figure 43 should undertake the function of the pump sump. By taking a view at the new outlet design, it becomes obvious that the point where the water leaves the outlet housing and enters the outlet pipe could be a bottleneck.

The next calculation should visualize if a pump is able to reach the necessary flow speed to change the total amount of water stream once. The cross-section area of the outlet pipe as seen in the figure was assumed with 0.04133 m²:

$$v_{necessary} = \frac{741\left[\frac{m^3}{h}\right]}{0.04133\left[m^2\right]} = 17928.86\left[\frac{m}{h}\right] = 4.5\left[\frac{m}{s}\right]$$

This velocity should be reachable by a pump, and therefore it should be possible to sluice out at least a big amount of contaminated water and reduce the fine content of solids in the system.

With these calculations it can be assumed that it is possible to install this new chip washer outlet in existing lines and that this installation would provide a benefit for the efficiency according to the arguments mentioned before. The new outlet is visualized in the following Figure 43 and Figure 44:

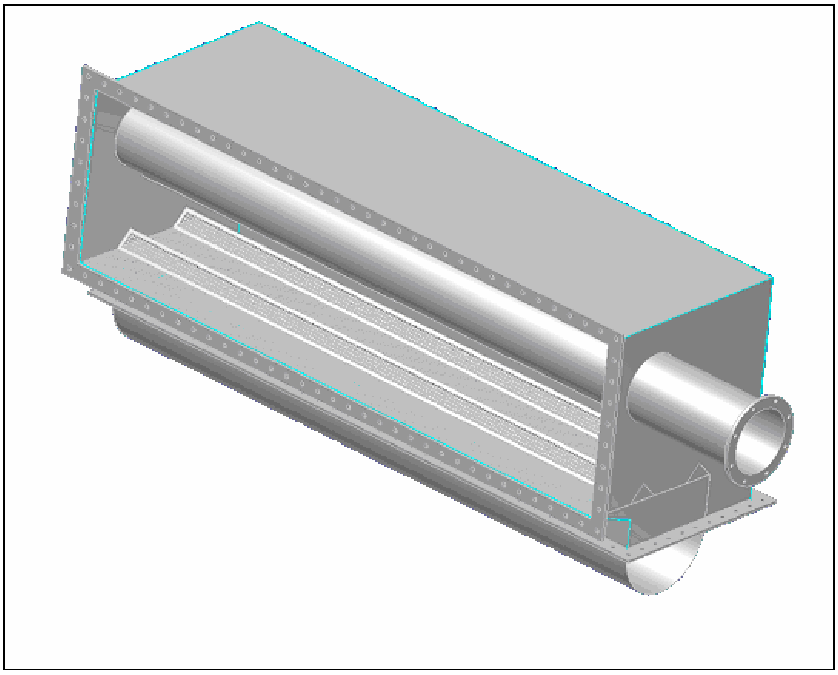

Figure 43: Front view of the new outlet channel design

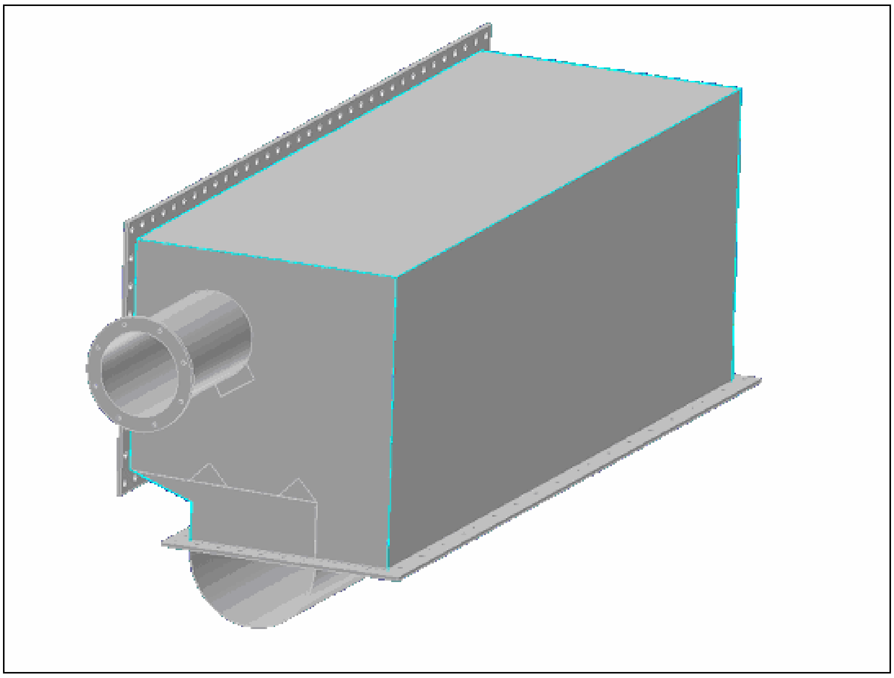

Figure 44: Back view of the new outlet channel design

In the existing systems, the chip water mixture coming from the chip washer flows over a weir into the chip pump sump. As this point of the washing process was only used for transporting the chips further, the idea came up to install an additional separation unit. The task of this unit is to increase the separation efficiency of the system, especially with regard to small particles. The main characteristic of the newly designed outlet is a sieve plate with two weirs. Also the floating direction side of the weirs should be manufactured as a sieve to increase the screening area. The height of the weirs has to be high enough so that the stream of water and chips constantly flows over the first weir and a tailback is not generated.

As shown in Figure 44, after the first weir a nozzle sprays water in the direction of the sieve plate. On the one hand this forces the chips over the second sieve weir, and on the other hand it removes the last adhering components from the chips. A plugging of the first weir by for example heavier chips should be prevented by the nozzle in the chip washer, which forces the chips through the outlet. It can be expected that the separation efficiency will not be hundred percent, mostly because a constant stream of chips to the chip pump has to be secured, but a noticeable reduction of small particles in the chip/water mixture should be achieved. The water coming from the chip washer will be separated from the chips and transported to the sedimentation tank by a pump. The contaminated water outlet from the separation unit is only indicated in the figure, because it has to be adapted to the different mounting situations in the already running lines. Because of this separation process, the concentration of chips entering the pump sump will be too high to be transported to the drainer screw. This can be counteracted by an additional water inlet at the top of the pump sump to guarantee the required 5% solids in the suspension to make it pumpable.

5.3.5 Bottom inlet

The bottom inlet in use has two main disadvantages. The first one is that the water stream that enters the washing process can be raised up to nearly any desired level. As a consequence thereof it happened in the past that the stream coming from the bottom inlet was higher than the inlet stream and the functionality of the washer did not exist anymore. A second disadvantage which results from the present construction is that the wash water input is situated right above the sluice arrangement.

By situating the inlet at that point, it can be assumed that a turbulent layer above the sluice will be generated as water incoming in two streams mashes up in this zone and flows upwards in the washer. In connection with the sluice intervals, the suspicion is obvious that sedimentation of particles will be suppressed and only very heavy particles can be sluiced out. Depending on the contamination grade in the process, the sluice opening interval can vary from 300 to 1800 sec. [Andritz internal]. It becomes obvious that the process operator has a wide range of opportunities to run the process. This must be another issue in the further development process, because a not well adjusted sluice arrangement also reduces the washing efficiency.

The disadvantages mentioned above led to the following new bottom inlet design as visualized in Figure 45:

Figure 45: New bottom inlet design

By taking a view at the newly designed bottom inlet, it becomes obvious that compared with the old system also the dimensions did not change. The new inlet design consists of a wash water inlet pipe with a smaller diameter than the outlet pipe and a nozzle arrangement on top of the inlet pipe. As seen in Figure 29, the inlet pipe is welded into the outlet pipe. The diameter of the nozzle arrangement is the same as the diameter at the bottom inlet of the washer. This fact is necessary for a very easy installation, because until the requested height the nozzle arrangement can just be inserted in the bottom aperture of the washer by dismounting the old wash water inlet and installing the new inlet instead. The requested height for the nozzle location should be found out in trials. The different diameters of heavy particles will probably be one of the main problems when determining the optimal gap-size. The nozzle must be adjusted in such a way that heavy particles can sink through the gap between washer housing and nozzle (see also Figure 29) into the outlet pipe, but heavier chips would be held in the process. Depending on the mounting situation on site, the connection pipe between the sluice arrangement and the bottom inlet should be prolonged to enlarge the calm zone above the sluices. The biggest advantage of the new system is that once heavy particles enter the gap, they sink down on top of the sluice and will not be whirled up again.

5.4 Cost estimate for the selected concept

A detailed cost estimate for the selected concept is in so far difficult as the mounting situation varies from site to site. For the inlet, outlet, and bottom inlet itself it can be assumed that the manufacturing costs of the new designs will be slightly higher than for the old system as there are no rotating parts or difficult surfaces to produce and the companion dimensions to the chip washer stay the same. It can be supposed that the price for a chip washer will not rise noticeably. Today all chip washers are manufactured externally and for new sites, this procedure will probably be maintained. A make or buy decision has to be taken when a customer decides to install only the upgrade products of the new design. Also the mounting costs at the site should be included in a serious cost estimate, but as the situation is different at every site, an estimate cannot be given.

The biggest cost factor will probably occur in the installation of the piping. At least three new water supply pipes and one outlet pipe have to be installed. Whether the three supply lines can be connected with the existing pipes, or new pipes have to be installed has to be considered locally. Also if additional pumps are needed to guarantee the system pressure can only be decided locally, depending on the situation. It should be possible to include the outlet pipe into the water recycling cycle where contaminated water will be transported to the sedimentation tank, but it will be necessary to install a pump in the outlet pipe. The reason for this fact is that on the one hand the transport of the contaminated water to the sedimentation tank has to be guaranteed; on the other hand the expected separation efficiency of the sieve plate has to be reached in the outlet (see also theoretical calculations, Chapter 5.3.4). The size of the pump (in the outlet pipe, see also Figure 43) depends on the amount of water that should be changed in the newly designed outlet channel and has to be found out in trials. As the total amount of water is expected to be constant, just the distribution will change. The dimensions of the units of the water recycling cycle do not have to be changed and no additional costs will occur.

Due to the different site conditions, a detailed serious cost estimate can again not be calculated.

6 Conclusions and recommendations

A well working chip-washing unit is of utmost importance for an efficiently working mechanical pulping process. Leaving the chip washer, the wooden chips must be free from physical contaminants, because they cause wear on subsequent equipment and further increase maintenance costs and plant downtime. The main function of a washer is to reduce heavy material from the chips, while fine particles remain suspended in the water. These fine particles are eliminated from the process with the washing water in the dewatering screw. It was a main topic of this work to improve the washing efficiency, investigate a proper way to measure it and find new design concepts to reduce fine particles as early as possible.

At the beginning of this work, the different chip washer sizes available on the market were evaluated to demonstrate the most common size in use. Following the Andritz nomenclature, the chip washers HE 2000 (384 - 576 t/d) and the HE 3000 (600 - 936 t/d) will probably be installed in a large number. The total amount of installed chip washers was gained by a marketing research. As a result of this research, with the available data at hand the present potential market in mechanical pulping for service business lies at 449 mechanical pulping lines worldwide. It has to be mentioned here that this count was calculated very conservatively, in order to give an overview of the potentially installed washers. In reality, it can be assumed that the number will be even higher, because in these calculations the installed chip washers in chemical pulping processes and in fibreboard lines are not included.

A former diploma thesis commissioned by Andritz in 2008 dealt with the topic of washing efficiency. By taking a view at the results, it becomes obvious that the quality of the washing process has an impact on the life time of refiner plates and an optimized washing may prolong the plate life time. The process points of taking the samples were chosen wisely and should be kept for further investigations to measure the efficiency. Nevertheless it must be considered here that the results of this work can just be seen as a reference point for testing efficiencies and not as representative, because of the small amount of samples, the variety of processes and the quite short investigation time. Also the fact has to be mentioned that the contamination grade of the washing water entering the process and a not well adjusted sluice arrangement may have an impact on the washing efficiency.

Existing attempts to reduce fine particles, for example by installing a cyclone in the process did not lead to the desired success.

Therefore several new chip washing concepts were created during this work. After evaluation by an expert panel, one was chosen that is easy to install, fits in almost every chip washer and is cheap in maintenance and very customer friendly. The author recommends, to choose one plant for the installation of the upgrade product for the chip washer, to, test the efficiency of the washing for at least one plate changing interval with the old system, install the new system and test again. So the quality of the upgrade product can easily be demonstrated to customers. With the knowledge gained during this work, it can be expected that this new concept provides the opportunity to raise the washing efficiency with low effort and thus improve the plant performance, prolong the refiner plate lifetime and reduce the total operating costs. These facts make this upgrade product unique compared to the competitors, very attractive to customers and should help Andritz to enlarge their specific market share.

7 Register

7.1 List of Tables

7.2 List of Figures

7.3 List of Pictures

7.4 Bibliography

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7.5 Appendix

Appendix 1 shows all decided and planned projects for new mills, new lines and capacity expansions worldwide until 2015. In this appendix, only mechanical and chemi-mechanical processes are mentioned. Additional information:

Fibres

- hardwood (hw)
- softwood and sawdust (sw)
- bleached (bl)
- unbleached (unbl)

Pos.	Status	Period*	Company	Grade	Mill location	Integrated capacity change 1000 t	Total capacity change 1000 t	Description
1	Decided	2011	Nippon Paper Industries Co., Ltd.	bl sw SCMP	Japan	50	50	restart
2	Decided	2012	An Hoa Paper Joint Stock Co.	bl hw CTMP	Vietnam	65	65	new line
3	Decided	2012	Empresa de Producción Social de Pulpa y Papel	bl sw CTMP	Venezuela	250	250	new mill
4	Decided	2012	Jiangsu Bohui Paper	bl hw CTMP	China	400	400	new mill
5	Decided	2012	Nippon Paper Industries Co., Ltd.	bl sw CTMP	Japan	50	50	restart
6	Decided	2012	International Commerce Import Export Company of Saigon	bl hw CTMP	Vietnam		100	new mill
7	Planned	2011	Arctic Paper Mochenwangen GmbH	bl sw gw	Germany	15	15	capacity expansion
8	Planned	2011	Tan Mai Paper Joint-Stock Co.	bl hw CTMP	Vietnam	130	130	new mill
9	Planned	2011	Melhoramentos Papeis Ltda.	bl hw CTMP	Brazil		15	capacity expansion
10	Planned	2011	Melhoramentos Papeis Ltda.	bl sw CTMP	China		15	capacity expansion
11	Planned	2011	Fujian Longyan Paper Corporation	bl sw CTMP	China	60	60	restart
12	Planned	2011	Henan Hengxing Paper Co., Ltd.	bl hw CTMP	China	300	300	new line
13	Planned	2012:	Tan Mai Paper Joint-Stock Co.	bl hw CTMP	Vietnam	230	230	new mill
14	Planned	2012	Henan Fuyang Longfen Paper Co., Ltd	bl hw CTMP	China	100	100	new mill
15	Planned	2012	Shandong Huatai Paper Co., Ltd.	bl hw CTMP	China	300	300	new line
16	Planned	2012	Tan Mai Paper Joint-Stock Co.	bl hw CTMP	Vietnam	130	130	new mill
17	Planned	2012	Thanh Hoa Paper Mill	bl hw CTMP	Vietnam	50	50	new mill
18	Planned	2012	Pulp United (Pty) Ltd	bl hw CTMP	South Africa		165	new mill
19	Planned	2013	SCA Graphic Sundsvall AB	bl sw CTMP	Sweden		20	capacity expansion
20	Planned	2013	Shandong Asia Pacific SSYMB Pulp & Paper Co. Ltd (APRIL SSYMB)	bl hw CTMP	China	500	500	new line
21	Planned	2013	Tiger Forest & Paper	bl hw CTMP	China	300	300	new mill
22	Planned	2013	..	bl hw CTMP	Indonesia		250	new mill
23	Planned	2014	JSC Solikamskbumprom	unbl sw TMP	Russia	365	365	new line
24	Planned	2014	Shandong Asia Pacific SSYMB Pulp & Paper Co. Ltd (APRIL SSYMB)	bl hw CTMP	China	250	250	new line
25	Planned	2014	Tan Mai Paper Joint-Stock Co.	bl hw CTMP	Vietnam	100	100	new mill
26	Planned	2014	Tan Mai Paper Joint-Stock Co.	bl hw gw	Vietnam	100	100	new mill
27	Planned	2015	Dobrush Paper Mill "Geroj Truda"	bl hw CTMP	Belarus	50	50	new line

Pos	Status	Period*	Company	Grade	Mill location	Integrated capacity change 1000 t	Total capacity change 1000 t	Description
28	Planned	2015	Dobrush Paper Mill "Geroj Truda"	bl sw CTMP	Belarus	100	100	new line
29	Planned	2015	Estonian Pulp	bl hw CTMP	Russia		270	new mill
30	Planned	2015	Vologda Paper Manufacturing Mill	bl sw CTMP	Russia	300	300	new mill
31	Planned	2015	Papelera Tucuman S.A.	bl hw CTMP	Argentina	200	200	new line
32	Planned	2015	Itapagé S.A.	bl sw CTMP	Brazil	70	70	new line
33	Planned	2015	Guangxi Jingui Pulp & Paper Co., Ltd.	bl hw CTMP	China	600	600	new line
34	Planned	2015	Jinlong Pulp and Paper	bl hw CTMP	China	250	250	new mill
35	Planned	2015	..	bl hw CTMP	Indonesia		500	new line

Appendix 1: Pulp capacity changes by change period 2011 [Pöyry 2011]