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ANALYSIS OF THE CONSTRUCTION AND OPERATION OF SYSTEM WOOD CHIPPING AND TRANSFER CHIPS

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ABSTRACT

The uniformity of pulp and the productivity of a pulp mill are influenced by many factors, but chip can be the most important. The chips have to be small enough so that chemicals and heat can penetrate and diffuse into the wood material so that the whole chip is cooked in a homogenous way. In case of too large wood pieces, the center of the chip will be at least partly uncooked. Thus, manufacturing plants strive to produce chips homogeneous size and shape.

However, many manufacturing plants have difficulty obtaining homogeneous chips. The opportunities for improving chip quality are, inter alia, in the system of chipping wood and transport of wood chips. This paper will show how the chip quality problems at the industrial plant can be solved.

KEYWORDS: Wood chipping, chip formation, disc chipper, transfer chips.

INTRODUCTION

In the pulp and paper industry, many studies have been carried out on wood chipping to understand the formation process of the chips. This industry looks for suitable chip dimensions with high interest in chip thickness (Borlew et al. 1970). Disc chippers are commonly used to crush raw wood into chips of a certain size. The analysis of the chip formation is quite complicated, because wood is an anisotropic, heterogeneous and hygroscopic material, and because during the wood chipping process, variables interact in an unexpected manner (Uhmeier 1995, Twaddle 1997). A common demand from the pulp and paper industry is the smallest possible variation of certain chip population parameters. A narrow distribution promotes uniform product properties, e.g. in chemical impregnation processes, and is generally recognized as a characteristic of a high quality product. Wood chips used for chemical pulp must be of relatively uniform size, though optimum size may vary depending on the wood species. Penetration of the pulping chemicals and thus the cooking time is considerably determined by chips length. This means in practice that the industrial plants that wood chipping strive to produce chips homogeneous size and shape. Normally, a relatively thin chip with a minimum of fiber damage as well as a narrow chip size distribution is desired.

Study of wood chipping and pneumatic conveying system for wood chips were carried out in manufacturing plant in Poland. The study showed many operational problems related to production of a large amount of small-sized chips in the process of wood chipping. It caused difficulties in further technological processes. Chipper parameters critical to the production of quality chips include spout angle, knife edge angle, lambda angle, knife speed, and chip length setting. The uniformity of chip size and the percentages of each chip size fraction produced by a chipper are keys to pulping performance. Pulp production, pulp strength and pulp quality are directly tied to chip size and chip quality (Hellström et al. 2009, Law et al. 2000, Abdallah et al. 2011). The oversize fractions and fines are not considered good for cooking. Oversize and undersized fractions can also cause mechanical problems in the case of the use of digesters of continuous operation – Kamyr. Fines fractions do not influence especially the production of cellulose in batch digesters.

The economic benefits of higher quality chips in pulping has intensified the focus on improving chipper performance (Spinelli et al. 2014, Hartler 1996). The negative effect of oversize chips, pin chips, and fines in chemical pulping, and the general benefits of uniformity in chip thickness, has motivated a re-examination of the factors critical to chipping which affect chip thickness distributions and chip size generation.

The aim of this article is to show, inter alia, the impact of the most important factors in the wood chipping process on the quality of produced chips.

MATERIAL AND METHODS

The study was performed at the manufacturing plant with the system wood chipping and pneumatic conveying system for wood chips. The wood chips were produced in the disc chipper (made in Kofama) with six knives. The diameter of the disk was 2350 mm. Fig. 1 show a diagram of the production of chips of pine pulpwood.

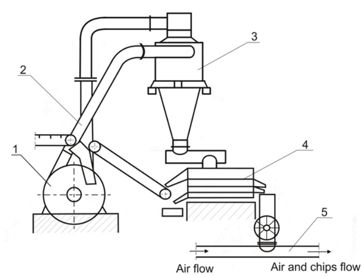

Fig. 1: The diagram of the production of chips of pine pulpwood
1 - disc chipper, 2 - pneumatic transport of wood chips from the chipper to the cyclone, 3 - cyclone, 4 - screening machine, 5 - pneumatic conveying system for wood chips.

The wood chip fractions were analyzed to assess the quality of chips. The fractionation process of chips was carried out on laboratory machine (wood chips screening machine). Nine sieves with holes were used to classify the chip sizes. The sieves holes have the following dimensions: Ø 32, 25, 22, 19, 16, 13, 9, 6 and 3.

The samples wood chips with a weight of 1 kg from specific locations of the production of chips, ie: After the chipper, cyclone, the screening machine and after the pneumatic conveying system, were taken to testing.

Then, the chips were poured into the screening machine and after 10 minutes of operation, the chips were weighed from each sieve. The weights of wood chips, was determined by a weighing scale with a precision of 1 g. For each of the next sample of chips was performed three times the measurements. From the measurements was calculated the arithmetic mean.

RESULTS AND DISCUSSION

The results of measurements of particle size distribution of wood chips

The results of measurements of particle size distribution of wood chips for pulp mill are shown in Tab. 1 and Fig. 2.

Tab. 1: Particle size distribution of pine wood chips, taken after the disc chipper, the cyclone and the pneumatic conveying system for wood chips.

Dimensions of the holes in the sieves (mm)	Particle size distribution of pine wood chips (%)			
	The fraction of wood chips after the disc chipper (A)	The fraction of wood chips after the cyclone (B)	The fraction of wood chips after the pneumatic conveying system for wood chips (C)	Notes
32	18.5	4.5	1.4	Oversize fraction
25	18.0	11.0	5.7	Accept fraction (desired)
22	11.8	8.0	4.9	
19	14.3	8.8	18.4	
16	12.7	14.0	13.8	
13	11.7	22.5	8.3	
9	10.5	24.2	37.8	The fraction too small (pins and fines)
6	1.2	4.0	9.1	
3	0.9	2.5	7.8	
0	0.4	0.5	1.9	

Notes: oversize and fraction to small is fraction of the waste.

The results show that the share of good chips in all measurement series was less than 80 % relative to the total weight of the chips. The amount retained on each sieve is divided by the total weight of the sample to give a percentage. When wood chips pass through subsequent devices is observed to increase the amount wood chips too small. The fractions a chip with a small nominal size that have passed through a pneumatic conveying system exceed the value of 30 %. Such a high percentage of fraction too small in the production of wood chips is unacceptable, both for the production of cellulose (particularly in case of using type digesters Kamyr - a type of continuous cooking system), but also wood-based panels, in particular particle board.

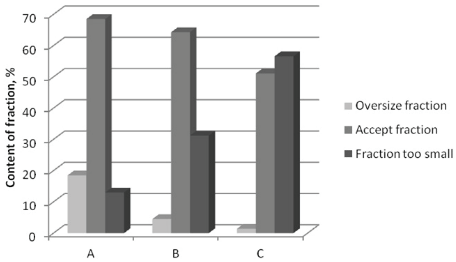

Fig. 2: The results of measurements of particle size distribution of pine wood chips for pulp mill.

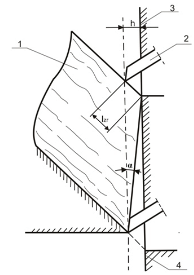

Fig. 3: The cutting wood in disc chipper 1 - log, 2 -- knife, 3 - chipper disc, 4 - anvil (α - clearance angles (pull-in angle), lzr - chip length, h - knife height).

The results (Tab. 1, Fig. 2) showed that large amounts of waste fractions are produced mainly:

- in the disc chipper,
- the transfer of wood chips from the chipper to the cyclone,
- during pneumatic conveying system of chips to landfill.

Causes of poor quality of wood chips

On the basis of measurements and observations, it was found that the main causes of poor quality chips are:

1. Lack of continuity cutting during chipping logs.

Used disc chipper is designed for chipping of wood with a diameter of 150 - 450 mm. Meanwhile, the wood logs were most often with diameters of 100 - 150 mm. Lack of continuity cutting wood causes inter alia, impact work disc chipper causing weakening of the wood by its micro-cracks. The wood chips produced under such conditions are highly susceptible to cracking. Optimal cutting wood occurs if there is continuity of cut logs i.e. at anytime at least one knife is in the cutting zone (Fig. 3).

Studies have shown that only in a few cases is ensured process of continuous cutting. When there is no continuity of cut logs may occur different cases the position of chipped wood relative to the knives and disc, depending on the applied clearance angles α (pull-in angle) Hartler (1996) and Fig. 4.

In the first case (Fig. 4a), there is a strong pull-in of the wood for too large values of the clearance angle α. The chipping logs for large values of the clearance angles causes:

- production of large amounts pins and fines
- production of chips of different sizes
- strong crushing and cracking of wood

In the second case (Fig. 4b) there is a pull-in of the wood for too small values of the clearance angle α. The chipping logs for small values of the angle α leads to production of significant amount of chips too small (pins and fines).

The third case (Fig. 4c) is acceptable. However while chipping log for such angles, the wood reflection from the disc occurs. This causes formation of chips of different sizes and micro-cracks wood and consequently to the weakening and cracking of the formed chip. Chips are also damaged by the compression forces when the knife hits the log. The size of damage chips depends on the chipper design, condition of the knife and sharpness angle of knife β.

The most appropriate wood chipping is shown in Fig. 4d. The angle α should be α4 < α< α3.

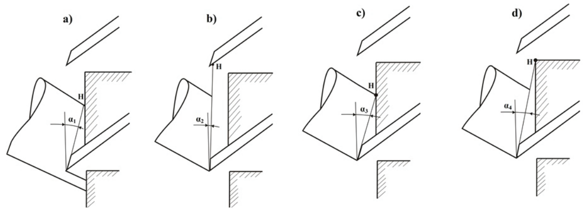

Fig. 4: Wood cutting depending on values of clearance angle.

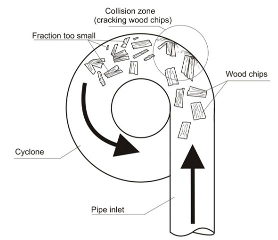

Fig. 5: Cracking wood chips in cyclone.

2. Excessive kinetic energy of the ejected wood chips from the chipper.

The excessive speed wood chips in the pipe inlet to the cyclone and the cyclone causes damage to the wood chips (cracking wood chips). The direct cause of this adverse event was too high speed disc with knives (Fig. 5).

Speed of cutting in the disc chipper has a big impact on the quality of produced wood chips. Cutting speed above 25 $m.s^{-1}$ will cause a significant increase the chips too small. It is therefore necessary to design chipper for speed of cutting not exceeding 20 - 25 $m.s^{-1}$ (Reczulski 2013).

Hartler (1996), (Hernandez and Jacques 1997) all agree that increasing cutting speed leads to the production of a higher percentage of both small chips and fines, since other variables remain constant. Manufacturers of chips use often largest cutting speed to achieve greater the efficiency of disc chippers. Such actions are inappropriate from the point of view of the quality of wood chips.

3. Poorly chosen values of wedge angle β of knife and settings of knife in the wood chipper.

It caused adverse effect of separating the wood chips from a wood log (the splitting and cleavage effect). The optimum case of separating the wood chips it is shearing effect (Fig. 6).

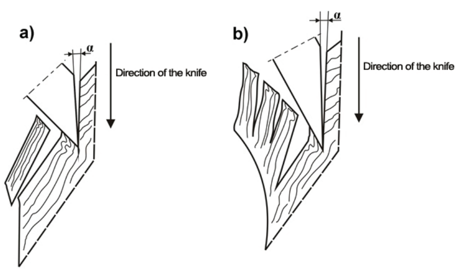

Fig. 6: The effect separating the wood chips from a wood log a) shearing effect, b) splitting and cleavage effect.

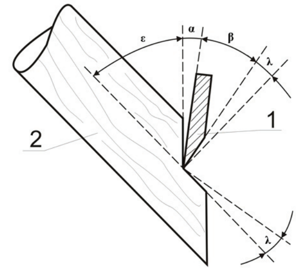

Fig. 7: Chipping configuration 1 - knife, 2 - log (α - clearance angles (pull-in angle), β - sharpness angle (wedge angle of knife), λ – complementary angle, ε–– feed - in angle).

The effect on the quality of wood chips has also an angle λ, that is located between line perpendicular to the axis wood log and a line parallel to the front edge of the knife (Fig. 7). Complementary angle λ influences the chip length to thickness ratio and can be used to control the chip geometry at least to some extent.

Increasing the value of the angle λ, reduces the amount of fraction too small. The complementary angle should be as large as possible due to the quality of produced chips (Hartler 1996). Practically, increase the angle λ, can be achieved by reducing the sharpness angle of knife β.

Reducing the value of the angle β, results in an improved quality of wood chips, but only in the initial period. Faster blunting of the knife contributes to increase the small chips in the chipping. The process of blunting the knives can be reduced by using better materials for the knives, but it is uneconomical way. Hellström et al. (2008) showed that chip formation process is highly dependent on the friction between the wood material and the chipping tool.

The best solution appears to use of the knife with a blade as shown in Fig. 8 (Uhmeier 1995). Then, the angle β, may be 30° or even less. This solution will increase the value of the complementary angle λ, and thus significantly improve the quality of produced chips with limited process of blunting of the knife.

The important thing is not primarily to produce chips with a specific thickness but that the thickness is as uniform as possible. This means that it is not necessarily so that the chipping tool should be as sharp as possible but rather that the chipping tools retain their characteristics over time (Hellström et al. 2008).

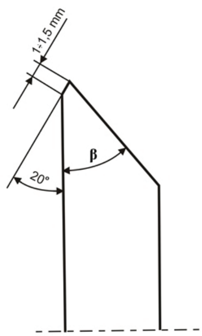

Fig. 8: The knife geometry.

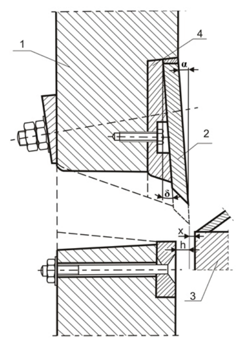

Fig. 9: The chamber shape chipping log. 1 – chipper disc, 2 – knife, 3 – bed knife or anvil.

4. The poorly chosen pneumatic conveying system for wood chips, in particular:

- Too long way pneumatic conveying system for wood chips
- Too many knees and bad shape of the knees in pipelines
- Lack of deflectors at the ends of the pipelines delivering chips to landfill.

Engelgau (1978) showed that the size of the chip can also be noticeably reduced after chipping by the impact between the chips and the chipper enclosure.

5. Incorrect operation of the chipper cutting system.

In many cases, it was found:

- The use of differentiated knife distance from disc "cut". It was observed that distance from the knives to disc was in the range from 18.1 to 21.1 mm, for a constant width of the knives.
- In subsequent knife slots use of knife shims of different angle δ (Fig. 9). The angle δ knife

shims determines (for the presented system cutting chipper) clearance angles α.
- Excessive and uneven wear of the knife slots.
- Adverse chamber shape chipping (through holes in the disc chipper) causing the wrong direction of the flow of wood chips and additional chipping wood chips (Fig. 9).

The parameters - h, α and x (Fig. 9) have (in addition to the angles α and β) a decisive influence on the conditions of chopping wood in the wood chipper and the quality of produced chips. Researchers Hellström et al. (2009), Law et al. (2000), Abdallah et al. (2011) all agree that use of differentiated heights h of each knives protruding from a disk surface (here from 18.1 to 21.1 mm) leads to cutting wood chips of different lengths l_{zr}. The use of different clearance angles α for all the knives causes the uneven feed rate wood logs and setting of the ends of the logs in parallel to the plane of the disc. Then the ends the logs can easily pass through the holes under the knives in the disc of chipper, especially with a large gap (x). This is the main cause of high content of splinters in the wood chips provided to the sorting.

Working with bent shaft of chipper (Fig. 10), which causes excessive vibration and the need to increase the gap between the knives and anvil (x) outside the optimal range, increases the production of wood chips of heterogeneous size and shape. The large gap between the knife blade and the plane of the anvil (x_{max}), the mainly increase of the content the fraction of oversized. Small gap (x_{min}) is a cause of increased fines fraction.

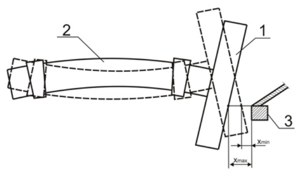

Fig. 10: The bent shaft disc chipper
1 - chipper disc, 2 - shaft, 3 - bed knife or anvil.

CONCLUSIONS

Observations and studies have shown that the cause of formation of small chips are often infirmities constructional, operational and the technological and especially, lack of knowledge about the basic functions of the individual elements of the wood chipper and their impact on the quality of the wood chips. The size of chips produced in the disc chipper, not only depends on a number of design parameters of the chipper but also on the physical properties of wood. Due to variability in the structure wood, any adjustment of the design parameters of chipper may be insufficient to ensure a uniform size of produced chips.

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