EFFECT OF REFINER LOAD ON PAPERMAKING POTENTIAL OF CELLULOSIC PULP

Marcin Dubowik, Piotr Przybysz, Marta Kucner, Kazimierz Przybysz, Edyta Małachowska

Lodz University of Technology, Institute of Papermaking and Printing, 223 Wolczanska Street, 90-924 Lodz, Poland

Abstract

This article presents the impact of laboratory refiner load on papermaking potential of paper. Bleached pinewood kraft pulp from one of paper mills was used for the investigation.

The main goal of the work was to investigate the influence of refiner load on properties of paper. According to scientific literature it is assumed that lower refiner load enable to obtain paper of high tensile properties but requires longer refining time. This concept was investigated in this work. Cellulosic pulp was refined in Valley beater and after refining properties of both pulp and paper were investigated. The obtained results have led to conclusions that there is a minimal refining load which is necessary produce paper with sufficient tensile properties. Moreover, observed differences in paper properties for different refining load after exceeding this minimal value are not very significant. Furthermore, detailed characteristics of paper refined using different load from 1,361 kG up to 8,165 kG are presented.

Key words: *refining, Valley beater, WRV, refiner load, breaking length, tear resistance*

INTRODUCTION

The paper pulp refining is of key importance in the papermaking process. The refining process affects the papermaking potential of the refined pulp. Additionally, the refining process is one of the most energy-consuming stages of the papermaking production.

Based on the current knowledge, the refining process can be defined as the process of structural changes of cell walls of cellulose fibers caused by a combination of the chemical interaction of water and mechanical energy. The nature and scope of these changes in the structure of fibers depend on the properties of the refined pulp and the refining conditions. In the course of the refining process an increase in strength properties of the produced paper is obtained due to the increase in the fibers flexibility [Laine et al. 2005; Lumiainen 2000; Mohlin 1975].

This phenomenon results also from the increase in the strength of bonds between individual fibers in paper structure. The strength of bonds between fibers is dependent on the strength of relevant bonds in the case of paper structure these are hydrogen bonds which are not significantly affected by the refining process and the bound surface – i.e. the contact surface of the fibers [Emerton 1957; Schmied et al.2013; Seth 2006].

This result is obtained through a process called fibrillation of fibers (Fig. 1).

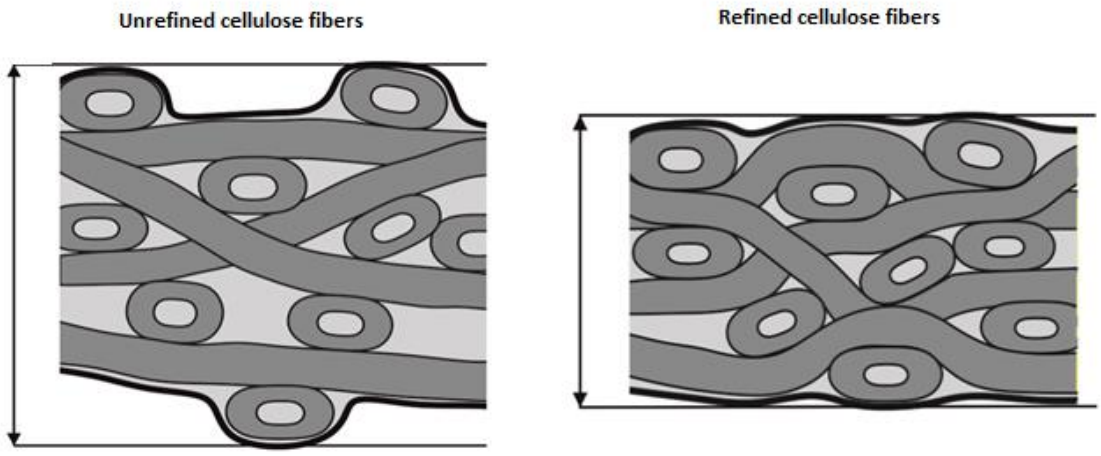


Figure 1. Models of structure of cross section of paper made from unbeaten fibers – stiff and beaten ones – elastic and flexible

Before the refining process cellulose fibers are rigid. This characteristic of fibers would not give a product desirable performance parameters. During the refining process, due to changes in the cell wall structure, fibers become adequately flexible and more elastic. As a result, the fibers become capable of forming sufficiently large bonding surface [Szwarcsztajn and Przybysz 1970; Wang 2006].

A very important factor in refining is the fact that it is an extremely energy-consuming process being at the same time energy-inefficient. According to current literature data the specific energy consumption in this process amounts to around 100-500kWh/t, while its energy efficiency is estimated to range from a fraction to a few percent [Illikainen et al. 2007; Cannelle 1999].

For years, scientists and professionals working in the papermaking industry have been seeking to improve the refining process. Both construction of the refining equipment and applied methods were subject to modifications. In the past, the research was conducted on the use of ultrasounds, pressure pulsation and cavitation [Focher et al. 1988; Gandini and Pasquini 2012; Joutsimo and Asikainen 2013; Kokta and Ahmed 1998; Martin-Sampedro et al. 2011; Mohlin and Petterson 2002; Szwarcsztajn and Przybysz 1970].

The most recent investigations regard the implementation of enzymatic treatment of pulps before refining- so called enzymatic pretreatment in order to reduce the specific energy consumption in the process. These methods, however, have not brought significant progress to date so as to streamline the refining process.

It was noted that it is necessary to better understand the mechanism of refining in order to achieve significant progress of the process.

According to the latest knowledge the following factors impact the industrial process of pulp refining: properties of fibers, the load of the refiner, the flow of pulp through the refiner, the pulp concentration and its temperature. Industrially, most of these factors are maintained at a constant level. Therefore, the load of the refiner is the only practical indicator to measure the intensity of pulp treatment in the process of refining [Lumiainen 2000].

The intensity of pulp treatment while refining as a result of load variations has a significant impact on energy consumption and performance properties of the obtained paper.

Given the important role of refining in the papermaking process and occurring changes of the pulp properties it was determined that investigating the impact of the load of a refiner on the papermaking potential is an important issue, particularly for industrial practice.

MATERIALS AND METHODS

The industrial air-dry bleached kraft pine pulp was subject to investigation supplied in the form of sheets. The basic parameters of the unrefined pulp:

- Schopper-Riegler freeness: 11°SR,
- WRV of the pulp: 91%,
- tear resistance: 413mN,
- breaking length 1470m.

The pulp was prepared for testing according to the following procedure: a weighted pulp sample (460g d.w.) was soaked in water overnight before refining. Next, the soaked pulp was shredded into flakes of 2x2cm and it was subject to refining. The process of refining was performed in the Valley beater (ISO 5264-1:1979). In the course of refining the only variable was the load. The process was conducted using the following loads (Table 1).

Load number	1	2	3	4	5	6	7
Loading value [kG]	**1,361**	**2,268**	**3,629**	**4,536**	**5,897**	**6,809**	**8,165**

Table 1. Various loads of Valley beater

Other conditions- such as, among others, the pulp flow, the pulp concentration and its temperature were maintained at constant values. The refining of studied pulps using various loads was conducted until freeness 30°SR was obtained.

Following the process of refining, the pulp sample was transferred to a laboratory mixer and by adding water it was diluted to obtain the concentration of fibers 0,5%

Properties of the pulp

After the refining process was carried out at different loads the following measurements were performed:

- Schopper-Riegler freeness (ISO 5267-1:2002),
- WRV of the pulp (ISO 23714:2014).

Properties of paper

Standard laboratory sheets were made using a Rapid Koethen appliance (ISO 5269-2:2007). Each of studied sheets had a grammage of 75g/m² (ISO 536:2012). The acceptable deviation from the predetermined grammage was +/-1g/m². The properties of the resulting paper samples were tested after prior conditioning of the samples. The samples were subject to conditioning under standard conditions in accordance with the norm ISO 187:1990.

The following measurements of the properties of paper samples were performed:

- breaking length (ISO 1924-2:2010),
- tear resistance (ISO 1974:2012).

RESULTS AND DISCUSSION

During the treatment of the tested pulp sample at different loads of the refiner changes of pulp properties occur which affect the properties of the resulting paper.

As the load increased, the time required to obtain a similar degree of Schopper-Riegler freeness of refined pulp shortened. It is shown in Figure 2. The most dynamic changes in the time required to obtain freeness 30°SR occurs between the loads of 2,268 and 3,629 kG. In the course of further loading of the Valley beater the time is continually reduced.

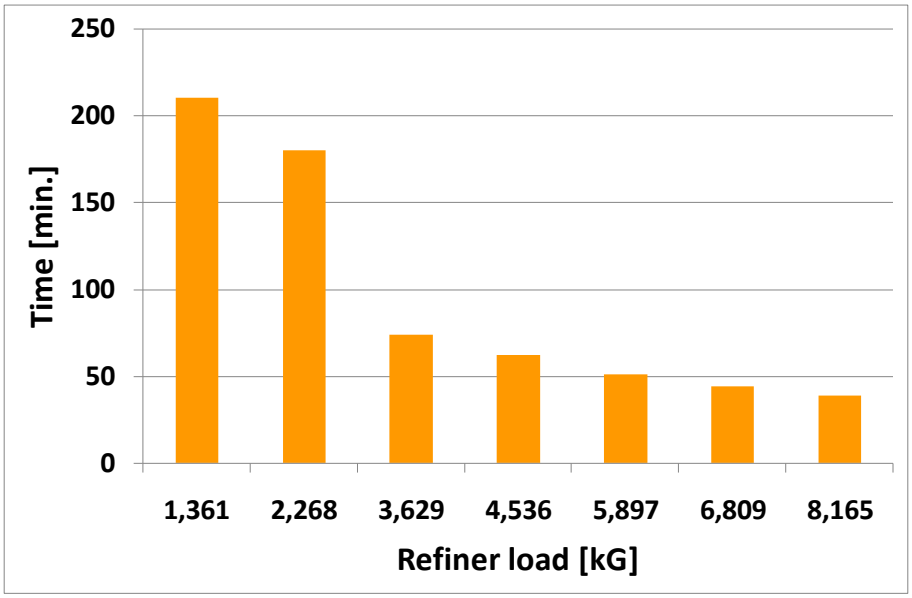


Figure 2. Progress of changes in time of using various loads of Valley beater

Figure 3 shows the WRV of the pulp for pulps with a degree of Schopper-Riegler freeness of 30°SR, which were subject to treatment with varying intensity. The results show slight differences in the values of the WRV which fall within expanded measurement uncertainty.

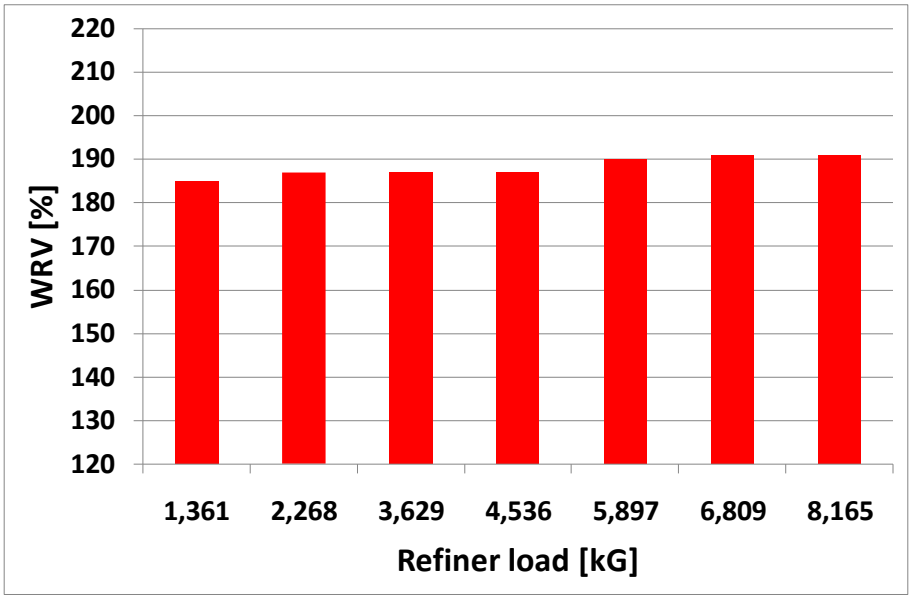


Figure 3. Progress of changes in WRV of the pulp of using various loads of Valley beater

Differences in properties can also be observed in relation to the properties of sheets obtained from pulps treated with varying intensity. Figure 4 shows the trend of breaking length changes of paper with the use of the pulp treated in a more intensive manner. It can be noted that the highest rate of changes occurs between the 1st and 2nd load of the refiner. As the load increases, the breaking length increase is insignificant.

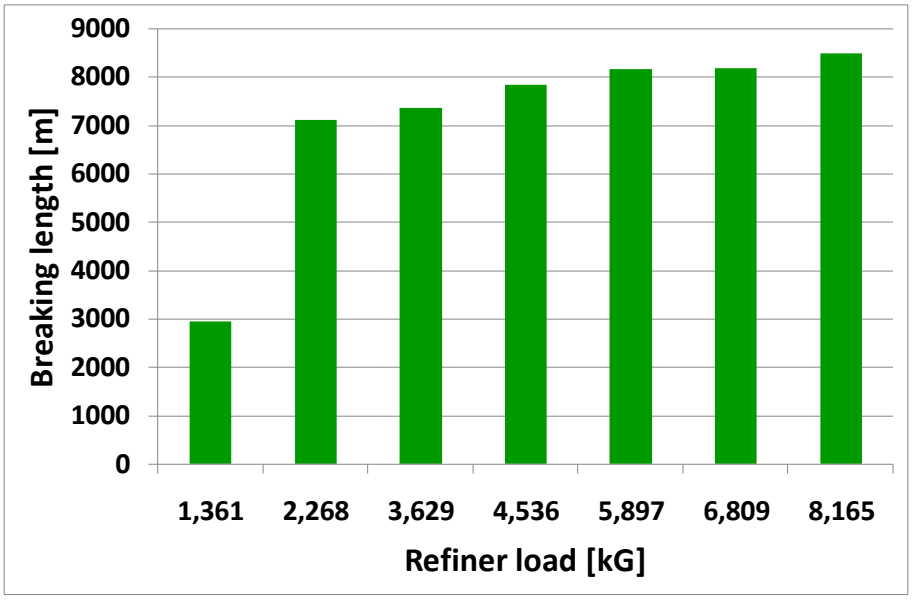


Figure 4. Progress of changes in breaking length of using various loads of Valley beater

The result of variations in the load of the refiner are also the changes of tear resistance (Fig. 5). It can be seen that a virtually linear decrease of tear resistance occurs with further loading of the refiner. The tear resistance value obtained for the pulp beaten at the highest load is by 30% lower than the tear resistance value at the lowest load.

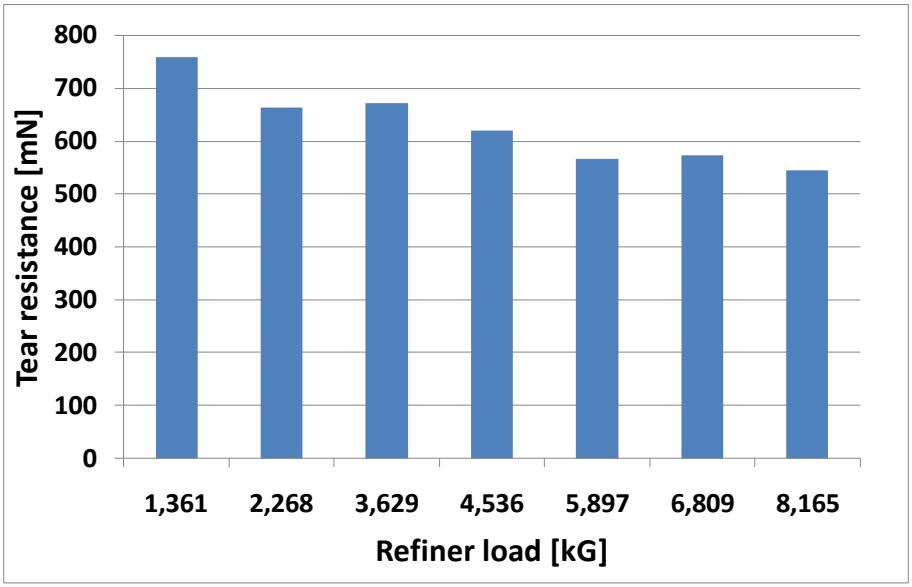


Figure 5. Progress of changes in tear resistance of using various loads of Valley beater

CONCLUSIONS

1. As the intensity of the refining process changes, the time of the process becomes shorter.
2. In the course of refining the pulp to the same degree of Schopper-Riegler freeness with the use of the refiner loaded differently, the pulp with varying static and dynamic strength properties is obtained.
3. Despite the fact that the values of the WRV of the pulp being at the same level suggest the absence of changes in the properties of paper, the changes in the properties of the finished product occur.
4. As the load of the refiner increases, the breaking length of paper increases respectively. This is the result of expanding surface of bonds between fibers.
5. During the refining process of fibers at varying intensity, changes of dynamic strength properties of paper also occur. A virtually linear decrease in tear resistance with a low rate of changes gives rise to a presumption that changes in the diversity of fiber length occur very slowly.

The authors gratefully acknowledge that this work was financially supported by the grant LIDER/042/407/L-4/12/NCBR/2013 from National Center for Research and Development Poland (NCBiR).

REFERENCES

Laine, C., X. Wang, M. Tenkanen, and A. Varhimo. 2005. 'Changes in the fiber wall during refining of bleached pine kraft pulp', *Holzforsch*. 58(3):233-240

Lumiainen, J. 2000. 'Refining of chemical pulp. In: *Papapermaking Part 1, Stock Preparation and Wet End. Papermaking Science and Technology*', Book 8. Ed. H. Paulapuro, Fapet Oy, Helsinki, Finland. Chapter 4,87-122

Mohlin, U.B. 1975. 'Cellulose fibre bonding. Part 3. The effect of beating and drying on interfibre bonding'. *Svensk Papperstidning*. 9:338-341.

Emerton, H.W. 1957. 'Fundamentals of Beating Process'. British *Paper Research Association*, United Kingdom. Chapter 3, 82-87.

Schmied, F.J., C. Teichert, L. Kappel, U. Hirn, W. Bauer, and R. Schennach. 2013. 'What holds paper together: Nanometre scale exploration of bonding between paper fibres'. *Sci. Rep*. 3:2432.

Seth, R.S. 2006. 'The importance of fibre straightness for pulp strength'. *Pulp & Paper Magazine Canada*. 107(1):34-42

Szwarcsztajn, E., and K. Przybysz. 1970. 'Badania nad zmianami zachodzącymi we włóknach i drobnej frakcji masy traktowanej ultradźwiękami'. *Polish Paper Review*. 37(10):331-334

Wang, X. 2006. 'Improving the papermaking properties of kraft pulp by controlling hornification and internal fibrillation'. Dissertation, Helsinki University of Technology.

Illikainen, M., E. Härkönen, and J. Niinimäki. 2007. 'Power Consumption and Fibre Development in a TMP Refiner Plate Gap: Comparison of LE- and Standard Refiner Segments'. *International Mechanical Pulping Conference*, Minneapolis, MN (USA).

Cannelle, E. 1999. 'Mechanical Pulping Technologies Focus on Reducing Refining Energy'. *Pulp & Paper*. 73(5):63-66.

Focher, B., A. Marzetti, and V. Crescenzi. 1988. 'Steam Explosion Techniques'. Fundamentals *and Industrial Applications*, Milan, Italy.

Gandini, A., and D. Pasquini. 2012. 'The impact of cellulose fibre surface modification on some physico-chemical properties of the ensuing papers'. *Industrial Crops and Products*. 35(1):15-21.

Joutsimo, O.P., and S. Asikainen. 2013. 'Effect of Fiber Wall Pore Structure on Pulp Sheet Density of Softwood Kraft Pulp Fibers'. *BioResources*. 8(2):2719-2737.

Kokta, B.V., and A. Ahmed. 1998. 'Steam Explosion Pulping'. In: *Environmentally Friendly Technologies for the Pulp and Paper Industry*. Ed. R.A. Young, and M. Akhtar, John Wiley & Sons Inc., New York, USA. Chapter 6, 191-214.

Martin-Sampedro, R., M.E. Eugenio, E. Revilla, J.A. Martín, and J.C. Villar. 2011. 'Integration of kraft pulping on a Forest Biorefinery by the addition of a steam explosion pretreatment'. *BioResources*. 6(1):513-528.

Mohlin, U.B., and B. Pettersson. 2002. 'Improved Papermaking by Cellulase Treatment before Refining'. *Progress in Biotechnology*. 21:291-299