On Mechanical Pulp Production for Wood-Containing High-Brightness Paper Grades

Tom Lind
Process Engineer, Paper Technology Division, Pöyry Forest Industry Oy, Helsinki, Finland

Nicholas Oksanen
Division Manager, Paper Technology Division, Pöyry Forest Industry Oy, Helsinki, Finland

Jean Balac
Senior Process Engineer, Paper Technology Division, Pöyry Forest Industry Oy, Helsinki, Finland

Bruno Lönnberg
Professor Emeritus, Pulping Technology, Åbo Akademi University, Turku, Finland

Erik Persson
Project Manager, Holmen Paper Development Centre, Norrköping, Sweden

Olli Tuovinen
Research Manager, Metso Paper, Valkeakoski, Finland

Andreas Kvitvang
Process Engineer, Norske Skog Saugbrugs, Halden, Norway

ABSTRACT

The modern mechanical pulping industry confronts many challenges. These are often related to the reduction of the electrical energy consumption. However, the simultaneous pressure from the paper markets is forcing the industry to develop products, which have superior properties but are also cost-effective from the production perspective and are reasonably priced for the markets. This includes many quality- and production related issues to be considered. As an example, raw material pre-treatments could be applied to the mechanical pulp production, in order to produce “tailor-made” mechanical pulp, suitable for different wood-containing paper grades. When the competition is tough, small differences in the paper quality or process cost-effectiveness can be very significant. This means that development of the pulp/paper products must be connected to the development of the production processes.

INTRODUCTION

The main task in all pulping processes is to convert the wood structure to a fiber network, suitable for papermaking, and simultaneously try to preserve the initial properties of fresh wood. On a more detailed level, different factors should be recognized during the whole production chain (from forest to consumer, especially during the mechanical pulping processes), in order to ensure maximum raw material performance (e.g. brightness, opacity and sufficient strength delivery of the fibers). The share of mechanical pulp in typical modern paper grade furnishes may range from 50 to 70% in SC paper, from 40 to 60% in LWC paper grades and up to 100% in newsprint (TMP) [1]. Thus, the final paper properties are very dependent on the mechanical pulp properties. An important driving force in developing mechanical pulp properties is also to reduce the amount of reinforcement chemical pulp. Challenges to maximise the mechanical pulp properties and raw material performance (e.g. by well designed processes) become core issues with SC-paper grades.

Mechanical pulping requires considerable amounts of energy, particularly the refining processes, which in fact are coming closer to the traditional, more energy-friendly grinding processes. Concurrent media also force papers to focus on certain special properties, of which printability is one issue. In that respect, one may expect that traditional grinding – further developed for better controlled grindstone surfaces – might come into focus as a cheap process. Adding the advantages that could be achieved by various pre-treatments of the wood raw material, it could be possible to produce cheap mechanical pulps resembling the +100 mesh fraction in current groundwood. That fraction might be considered as an ideal pulp regarding sheet properties, e.g. strength and optical properties as well as printability.

The main challenges in mechanical pulp related challenges are mostly related to electrical energy consumption (as mentioned above). In some countries, VOC-emissions can also be considered to be problematic, which create challenges in design and operation of the mechanical pulping processes. The procurement of high-quality wood raw material is very central. PGW-processes have very high wood quality demand parameters, whereas this is not as critical for the refiner processes. Wood procurement often confronts competition in the raw material markets.
Recent studies regarding the interactions between the grinding process and wood raw material indicates that selective use of raw material might improve both strength and optical properties. In the GW process, wood with a high proportion earlywood and juvenile wood seems to give both good strength, high brightness and light scattering and, due to the flexible fibers, probably also good surface properties. This is in contrast to experiences from TMP, where similar wood results in good optical properties, good surfaces, but inferior strength/energy relation.

The general development of the paper industry is changing towards even lower grammages. Even higher brightness of the paper is preferred, simultaneously as the bulk and opacity of the paper must be increased. Rotogravure printing requires good smoothness of the paper surface, which increases the requirements for the mechanical pulp fiber length distribution. However, the minimization of the energy consumption in the mechanical pulping processes is still a very central issue.

The standard SC-A-grades are slowly being “disappeared” and most probably are included in the SC-B- grades in the future. SC-A+ can be considered as the “SC-grade of the future”. This can be seen in the recent activity in the peroxyde bleach plant investments. The general quality parameters of the SC-grades have been well improving during the recent years and the pricing gap between SC- and LWC-grades is closing. Thus, it would not be surprising if the SC-grades would start to threaten the LWC-markets as a substitute (Figure 1).

![Figure 1. The most usual printing and writing paper grades ranked according to the relative price and quality [2].](image)

From the papermaking point of view, perhaps the most challenging combination of parameters is to produce mechanical pulp for high-quality SC-rotogravure paper grades. Coarse fiber content must be kept very low, which is especially challenging with TMP-pulps. Separation of the water systems at mills with several paper machine mills together with TMP process water flow connections to these is a very important issue regarding the quality of the SC-paper. It is essential to avoid the carryover of the pitch components to the paper machine, apply counter current washing together with efficient latency removal and avoid thermal shocks on fibers.
In Scandinavia, the most widely used Norway spruce is actually also important for the chemical pulp industry. The mechanical pulp industry is forced to utilise all the spruce resources available while maximising the pulp properties. This is evidently possible only by careful pulpwood handling through limiting storage-related quality losses. It is challenging to achieve superior results if the raw material employed is negatively affected for some reasons, e.g. storage-related reduced initial wood brightness or generally poor properties in some certain forest stands. By efficient raw material handling and optimized mechanical pulping processes, a number of current negative impacts can be minimized. If the mechanical pulping processes cannot be adjusted for maximum recovery of the desired pulp properties (e.g. brightness), various pre-treatments of the wood raw material could be utilized.

Pre-treatments of the wood raw material can affect subsequent processes in many ways. Unbleached mechanical pulp brightness losses can be minimized by applying suitable pre-treatment conditions, e.g. carefully controlled wood-storage or separate pre-treatment stage(s). This has been proven in a number of earlier studies [3,4,5,6]. Drainage properties and/or strength properties of the fiber network can also be adjusted by pre-treatments, to achieve suitable conditions for a certain paper machine performance or affect the mechanical pulp properties in the final papermaking furnish. Mechanical pulp contains 25-35% fines, contributing to superior printing surface in the papers but simultaneously decreasing some pulp strength and drainage properties. This balance could be controlled by applying some pre-treatments in order to find optimal solutions for certain applications, both for paper production economics (paper machine speed) and paper quality.

Impacts of preconditioning and preheating

The pulpwood moisture content (MC) fluctuates with the storage conditions of a wood yard, e.g. the relative humidity and temperature of the surrounding atmosphere [7,8]. The wood MC can be raised to the maximum level (approximately 65%) by its submersion in water [3]. Accordingly, at a wood yard the MC-increase requires a longer wetting time [7,8,9]. The wood MC plays a significant role for the mechanical and elastic wood properties. Also the plasticisation of the wood polymers is highly dependent on the wood MC [10]. Dry wood is much stiffer than fresh and wet wood, and the stress needed to cause a failure is significantly lower for wet wood [11].

The effects of pulpwood temperature on the fiber release have also been investigated [4,5,6,12]. The fiber separation can be associated with different parts of the fiber wall depending on the pre-treatment conditions. At low preheating temperatures (20-60 °C), fiber separation occurs mainly in the bulk fiber wall, which leads to split or broken tracheids. At higher temperatures, a successful fiber separation occurs somewhere in the interface between the fibers, mainly between the middle lamella and the primary wall. It implies that application of high preheating temperatures would produce less damaged fibers also in industrial mechanical pulping processes. This offers a possible use for non-recovered steam in mechanical pulp mills. High-temperature conditions contribute to an improved softening of the lignin in the fibers, and thermal softening may provide energy savings in the fiberising process. Laboratory studies have indicated that a wood temperature exceeding room-temperature would lead to improved fiber separation with less energy input [4,5,6,13,14]. The general drawback of wood preheating prior to the mechanical pulping process is darkening of the pulp, which increases with the temperature [4,5,6,15].

This section presents preconditioning and preheating impacts (fibrillation, bleachability and effects on the lignin content development) on pulpwood aimed for PGW production. Pre-treatment effects on PGW pulp strength, optical properties and energy consumption have been reported earlier [16].

EXPERIMENTAL

The fresh wood MC was modified to achieve different levels by application of an earlier introduced procedure [17]. Preheating was done to obtain different temperature levels ranging from 0°C to 95°C. Earlier findings encouraged to pay attention to water-impregnated wood with MC 65% (with fresh wood as reference, MC 58%) and combine these parameters with preheating temperatures of 50°C and 95°C (25°C as reference). The laboratory grinding equipment was used in the experiments for simulation of the PGW grinding process [18]. Commercial-type ceramic grindstones were conditioned to a dullness level producing 150-freeness PGW at a specific energy of approximately 1200 kWh/t.

To evaluate the fibrillation of long fibers, the +30-mesh McNett-fraction was measured for WRV (Water Retention Value) and sedimentation volume/speed. The properties were compared with a coarse fiber fraction obtained with a pulp made of fresh wood without preheating (MC 58%, temperature 25 °C). The WRV describes the tendency of the pulp to retain water; high WRV indicates a better capability to include water and vice versa.
Bleaching experiments by applying sodium dithionite and hydrogen peroxide were performed in order to determine possible differences in the bleachability of the PGW pulps produced subsequent to certain wood pre-treatments. Several pulps were produced of pre-treated wood by introduction of variable energy. Pulps with a CSF value close to 100 ml were selected for the bleaching experiments performed by the HC/MC laboratory mixer. The bleaching trials implied a “typical” laboratory bleaching custom using a 1% bleach chemical charge for both of the chemicals employed.

The effects of pre-treatments on the pulp lignin content were measured by an acetyl bromide procedure developed for dry wood and pulp samples [19]. The lignin content was then determined based on the spectrophotometrical UV absorbance at 280 nm for the extract-free and freeze-dried samples.

**RESULTS**

For fresh wood the WRV seemed to increase clearly with increasing wood temperature (Figure 2). It may indicate that the fibers are flexible and also fibrillated. However, for water-impregnated wood no clear impact on the WRV could be seen. Regarding water-impregnated wood, already a low wood temperature seemed to achieve a high WRV. It was noticed that pulps made from water-impregnated wood achieve sedimentation more effectively, i.e. due to a better internal fibrillation the fibers appear more flexible, which also is supported by the WRV trends observed. Wood temperature seemed to play a role only in the case of fresh wood.

![Figure 2. Effects of wood temperature and MC on the WRV of the McNett +30 fraction (g water/g o.d. pulp).](image)

As stated earlier for the unbleached pulps, a high wood MC seemed to retard the temperature-induced brightness decrease, i.e. the brightness level was generally higher for water-impregnated wood pulps than for fresh wood pulps [16]. Dramatic changes could not be seen in the brightness of the bleached pulps as a function of the wood MC (Figure 3). The unbleached brightness behaviour was what could be expected from previous experiments, i.e. a clear drop occurred with increased wood temperature. It is interesting that the high-temperature darkening of the unbleached brightness could be compensated almost completely by bleaching. If pulp strength and drainage properties can be improved simultaneously, pulpwood preheating should be considered. Peroxide appeared to be sufficient in bleaching throughout the whole temperature range.
The results illustrate that decreasing lignin content was associated with increased wood temperature (Figure 4). This might explain earlier findings that increased shower water temperature increased the release of low-molecular lignin from the wood material [20], which is positive regarding the brightness reversion; although the released lignin amounts were relatively low in this case. Another interesting issue is the generally higher lignin level of pulps made of water-impregnated wood, which probably may depend on the modified temperature profile in the wood during grinding, which is caused by the high wood MC. A low temperature in the grinding zone may explain the high lignin content in the fibers.

**SUMMARY**

Based on the WRV-results, fibrillation of the fibers occurred in pressurised grinding when the wood temperature was elevated. The temperature affected the fibrillation mainly with fresh wood, while it had only a minor impact on water-impregnated wood. Bleaching of pulps produced of thermally darkened wood displayed a good brightness response. It was evident both for bleaching with dithionite and peroxide. The initial, unbleached pulp brightness seemed to determine the end result. As expected, decreased lignin in fibers was associated with high wood
temperatures. The fiber fractions of pulps made from water-impregnated wood provided slightly higher lignin contents than did fresh wood.

The experiments conducted provided further information on the impacts caused by pulpwood pre-treatments, which is confirmed by earlier results. Thus it may be established that wood raw material modifications lead to changes in final fiber properties. Small improvements of some papermaking features may become important, when competition in the paper markets and increasing raw material prices tend to limit the paper pricing. From an industrial perspective, the possibilities to establish such wood raw material modifications are economically not very challenging, when considering potential paper quality and production economic benefits.

References