ULTRA HIGH PRESSURE (10 - 12 bar) TMP AND IT'S ENERGY RECOVERY OPTIONS

Heinrich Muenster, Austria
Anders Hansson, Stora Enso, Sweden

Abstract

Traditionally TMP for graphic papers is produced at low chip preheating pressures of 1-2 bar(g) (or even at atmospheric pressure in the case of PRMP) for 1.5 to 3 minutes and at refining pressures of about 3.0 to 4.0 bar(g) in order to obtain adequate pulp properties at reasonable energy requirements and a recovered steam pressure which is high enough to be used in the dryer section of the paper machine without further compression. Many investigations have shown that the residence time of the chips at higher pressures/temperatures during preheating and refining has to be short and well controlled in order to avoid pulp discoloration and to keep the energy consumption at acceptable levels. Short preheating times, in the order of about 13 seconds and pressures/temperatures of about 5.5 bar(g)/162°C are used in the first refining stage of the RTS process.

Several limitations of existing commercial and pilot installations to operate at minimal retention times in preheating and refining at even high pressures/temperatures have hindered research work in this area. A recently modified pilot plant allows to produce TMP at pressures up to 12 bar(g) (appr. 192°C ) and at very short retention times. RTS-TMP was produced and ultra high pressure TMP at the practically shortest possible retention time. The results confirm the importance of short and well controlled exposure of chips respectively fibers to high temperatures in order to obtain proper fracture zones in the wood matrix and sufficient fines generation at comparable refining energy levels and to avoid excessive pulp discoloration. Options are presented how the recovered high pressure steam could be used for power generation, for efficient drying applications, for e.g. effluent evaporation prior to paper drying or as motive steam to boost low pressure steam to usable levels in order to improve the overall energy balance of TMP production.

Introduction

Refiner based mechanical pulping evolved from atmospherically operated 1, 2 or 3 stage RMP systems to first. stage pressurized refining and later, to two stage higher pressure TMP or PRMP operations. Typical TMP operating parameters were presteaming at 1-2 bar (g) steam pressure for 1.5 - 3 minutes. It was soon recognized that more than 90% of the energy applied in thermo-mechanical pulping is consumed for heating of the chips and the dilution water to refining temperature and to produce steam. Usual energy balances around TMP refiners do not even take into consideration the small amount of energy which is used for fiber separation, and development of fiber surface and bonding capability.

Driven by the second energy crisis in the early eighties it became an economical necessity to recover energy from the TMP process in the form of steam for use elsewhere in the mill most obviously for paper drying. Paper drying usually requires a steam pressure of 2-3 bar(g). In the beginning mechanical steam compressors were installed in order to increase the pressure of the recovered steam (1). It was however more desirable to raise the refining pressure to an adequate level. Thereby it had to be considered that a pressure drop of nearly 1 bar occurs when taking the "dirty" steam generated in the refiner to a cyclone for steam/fiber separation and via a scrubber to a reboiler for clean steam production by evaporating the clean condensate recirculated from the dryer section of the paper machine.

The presteaming and refining pressure could not simply be raised because of the known detrimental effects of the associated higher temperature, in particular a decline in pulp brightness and an increase in specific energy consumption. This increase in specific energy consumption was attributed to excessive softening of the lignin rich middle lamella and a preferential fiber separation in these zones contrary to more desirable fracture zones within the more cellulose rich cell walls.
In order to evaluate the practical operating limits for a high pressure thermo-mechanical pulping plant the effects of different combinations of steaming time and pressure on the brightness, the energy consumption and pulp properties were investigated at the pilot plant of the PPRIC (2). It was shown that the refining pressure can be increased to 620 kPa (5.2 bar(g)) without significant brightness loss if the time for presteaming at this pressure was reduced from 200 to 16 seconds. (Fig 1).

Fig.1: Brightness versus Preheating Pressure at Retention Times of 200 sec and 16 sec

At this short presteaming time the specific energy required to reach a certain burst index was less dependent on pressure than at 200 seconds. In fact the SEC to reach a certain tear strength was reduced (Fig 2).

Fig.2: Specific Refining Energy versus Preheating Pressure to reach a Tear Index of 9.0 mN.m²/g at Retention Times of 200 sec and 16 sec
In order to optimise for steam recovery it was obvious that a plug feeder or rotary valve had to be incorporated in the system between the preheater and the first stage refiner to allow for presteaming at lower pressure, (possibly atmospheric pressure in the case of PRMP) and short time high pressure refining in the first and even also the second stage. Such a type of 2 stage pressurized "tandem system" was first installed in a Finish mill (3). Some systems relinquished the pressure lock between the preheater and the refiner and operate with a high pressure boost across the refining zone. This resulted in a lower overall steam recovery rate because only the forward flowing steam had a high enough pressure in order to be recovered and used for paper drying.

In the early nineties the effect of refiner speed and other parameters on refining intensity were explored by K. Miles and D. May (4). This work formed a basis of the RTS-TMP process (5). In this energy saving process the retention time of the chips at high temperature and the refining intensity are optimised. Typical operating parameters today are chip retention times of 10-13 sec at 5,4-5,8 bar(g) and a higher refining intensity due to an elevated refiner speed of 2100-2300 rpm. Energy savings of 15 up to 20% are reported. Since then further efforts to reduce the energy demand of mechanical pulping centred around proper pretreatment of chips and other methods like high temperature LC refining.

**Discussion**

Today a widespread opinion is that it is difficult to avoid some darkening at very high pressures/temperatures even if the retention time is short. There seems to be some good research required to obtain a better understanding of the condensation reactions and chromophore production in lignin and hemicellulose caused by the application of high temperature steam (6). There is also belief that the energy demand to reach a certain freeness may go up due to a lower production of fines unless the refiner speed/intensity is very high.

On the other hand one could speculate that the dwell time and the transport of the material in the refining gap is significantly different at 2-3 times higher steam pressure because the volume of the steam is reduced to about one third and accordingly also the steam velocity and the drag forces on the fibers. Härkonen and others have shown that about 50% of the energy applied in the primary pressurized refiner is consumed in the inner part of the plates and appr. 50% beyond the pressure peak in the outer plate section. Due to the back-flowing steam in the inner section a significant amount of recirculation occurs which may be one reason for the inefficiency of the refining process.

On the other hand, beyond the pressure peak, a reduced steam volume and speed increases the retention time of the fibers in the refining gap and decreases refining intensity. Reducing the amount of recirculation and adapting the refiner speed/intensity to the high pressure refining regime may offer some improvement in energy transfer.

So far, however, limitations in pressure rating of existing TMP pilot plants and the difficulty to further shorten the retention time of chips at high pressure/temperature prior to refining hindered attempts to investigate the effect of higher refining pressures. This report describes refining trials in a high pressure (10-12 bar(g) in a laboratory TMP system at the Fraunhofer Institute (WKI) in Braunschweig, Germany.

**Experimental**

Initially the pilot plant was equipped with a chip hopper, a high compression 6" screw feeder (MSD), an impregnination/presteaming vessel which provides a retention time of 30 sec to 5 minutes, a pressurized 12" Andritz-Sprout Bauer single disc refiner with a variable speed motor of 90 kW( Fig 3).
I order to facilitate the high pressure, short retention time trials, the plant was modified so that the high compression screw is arranged rectangularly to the fast rotating refiner feed screw and as close as possible to the eye of the refiner (Fig 4).
The refiner feed screw in fact scrapes off the plug formed in the compression screw. Theoretically the retention time of the chips at pressure was calculated to be in the range of 2-8 sec depending on the speed of the feed screw. From the pressurized refiner the pulp is blown via a blow valve to a cyclone and discharged on a belt conveyor in order to simplify sampling.

The first trial run was made at RTS-TMP conditions i.e. 5.5 bar(g) presteaming and refining pressure and about 8 sec. retention time in order to have a baseline comparison. Then the pressure was gradually raised and samples were taken at 8, 10 and 12 bar(g) pressure in order to investigate the effect of pressure/temperature on brightness. In a second series of test runs which also started at RTS-TMP conditions the retention time was reduced to the practically possible minimum of 2-3 seconds and the specific energy input was increased stepwise from about 600 kWh/t to 1200 kWh/t. The samples were treated for latency removal and tested as per SCAN standards at the Stora Enso Falun Research Centre. The results will be presented at the conference (Fig.5).

**Options to use high pressure recovered TMP steam**

From conventional TMP plants and also from RTS-TMP operations usually "dirty" steam is recovered at a pressure of 3.0-4.0 bar(g). It is converted in a reboiler to 2.0-3.0 bar(g) clean steam by evaporating clean condensate. When TMP does not represent the 100% of the fiber supply the amount of recovered steam is usually not enough in order to fully satisfy the need for drying steam on the paper machine. In any case a back up system for steam supply has to exist. Usually paper mills operate a biomass or fossil fuel combined heat and power (CHP) plant, which also provides steam for paper drying. Quite frequently any amount of recovered TMP steam exceeding the design parameters is of little or no value to the mill, because it would mean that the steam extraction from the counter-pressure turbine is reduced and consequently also the valuable electricity production. Therefore it can be of particular interest to open up additional application routs for recovered TMP steam preferably at higher pressure/temperature.

In a P&P mill such applications range from various drying processes for sludges, wood waste and bark and BCTMP or chemical pulp drying to a possible use in MDF and particle board dryers.

Table 1 shows the various applications, the types of dryer used, their heating requirements (typically 150 - 180 (200)°C) and illustrates the fact that 10 bar(g) recovered steam can replace gas, thermo oil or fresh steam in fluidised bed, belt, flash and chemical pulp sheet dryers. Assuming a moderate 70% efficiency in TMP steam recovery and a plus 70% efficiency of most drying processes, about 50% of the electric energy used in TMP can in this way be recovered and "stored" as primary energy e.g. in the form of dried sludge or bio waste.

**Table 1. Possible use of 10 bar(g) recovered TMP steam in various drying applications (7)**

<table>
<thead>
<tr>
<th>Material</th>
<th>Type of dryer</th>
<th>Heating medium / temperature °C</th>
<th>Possible use of 10 bar(g) TMP steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludges and medium to larger particle wood waste</td>
<td>drum</td>
<td>gas / dry fuel 400-450</td>
<td>TMP steam can be used for preheating / drying</td>
</tr>
<tr>
<td>Small particle biomaterial and sludge</td>
<td>fluidized bed</td>
<td>thermo oil / steam 200-300</td>
<td>TMP steam</td>
</tr>
<tr>
<td>Sludges and small to medium particle biowaste</td>
<td>belt</td>
<td>gas / waste heat 150</td>
<td>TMP steam</td>
</tr>
<tr>
<td>(B)CTMP</td>
<td>flash dryer</td>
<td>gas / steam 1st stage 260, 2nd stage 180</td>
<td>TMP steam</td>
</tr>
<tr>
<td>MDF</td>
<td>flash dryer</td>
<td>gas / steam 160-180</td>
<td>TMP steam (even dirty)</td>
</tr>
<tr>
<td>chem. pulp</td>
<td>sheet dryer (air borne)</td>
<td>steam 180</td>
<td>TMP steam</td>
</tr>
</tbody>
</table>
Another possible use for recovered 10 bar(g) TMP steam is to first use it in 2-3 effects (considering boiling point elevation) for evaporation of TMP effluent and subsequently at 2-3 bar(g) for paper drying. Such a set up would allow to produce without additional energy costs clean condensate from the effluent stream which probably has the highest COD load in the mill if a proper counter-current water flow arrangement and tight water loops exist. Preferably such an effluent stream should be arranged from a low salt or "salt free" water loop so that the combustion of the concentrate is facilitated.

Fig 6 shows how 10 bar(g) steam could be used in a thermo-compressor to boost very low pressure steam and vapours to pressure levels where it can be used in belt dryers or in the dryer section of a paper machine (8).

Fig.6: Thermo-compressor massbalance for 10 bar(g) motive steam to boost low pressure steam

Quite often it has been discussed to use steam recovered from TMP for power generation. The following two cases illustrate how 10 bar(g) steam could be used in a condensing or in a counter-pressure turbine (9).
Assuming conservative efficiency factors, 5.5 MW (el) could be recovered from a 38-40 MW UHP-TMP operation via a condensing turbine (heat balance Fig 7).

Fig 7  Heat balance of using 11 bar(abs) steam in a condensing turbine for electricity generation.
The second heat balance (Fig 8) shows an arrangement where the 10 bar(g) steam is used for power generation in a counter pressure turbine and the 3 bar(g) exhaust steam is still used for paper drying.

**Fig 8** Heat balance of using 11 bar(abs) steam in a counter-pressure turbine for electricity generation and the exhaust steam at 4 bar(abs) for paper drying.

In both cases particular attention has to be paid to the proper turbine material selection in order to avoid erosion corrosion.

It is hoped that more experience can be gained in UHP-TMP refining preferably in an industrial scale pilot facility which could quite well be a steam pressurized refining system for MDF production which are typically designed for operating pressures of 12 to 14 bar(g))
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References


9. Sattler, F. Austrian Energy & Environment AG