Reducing dependence on softwood kraft pulp as a reinforcing component in groundwood publication papers

BY G. HARRIS

Abstract: This article discusses technical and process issues that influence softwood kraft pulp consumption in groundwood printing paper mills. Recent advances in pulping and papermaking have made it possible to reduce or eliminate softwood kraft pulp from some papermaking furnishes. Mills that employ more “established” technology should be aware of factors that enable “newer” mills to escape from established rules concerning the kraft requirement. The article also outlines technical requirements to minimize the kraft content of papermaking furnishes, which usually helps to minimize operating cost.

This paper discusses factors that influence softwood kraft pulp (SWK) consumption in publication paper mills and suggests means of reducing SWK consumption under certain circumstances. Both SCA and LWC mills typically use SWK, and they do so for the same general reasons of strength and runability, even though process details and sheet structure differ (i.e. coated versus filled). Mechanical pulp quality requirements are also similar for LWC and SCA since both grades demand a flat, stable paper surface, a “tight/dense” sheet structure (important for ink/coating holdout, surface strength) and high opacity. Hence, in this article, comments that apply to LWC are normally valid for SCA and vice versa.

This issue is driven by economics. Operating costs in SCA/LWC mills depend on the amount and individual costs of three furnish components, namely mechanical pulp, SWK and filler (or coating). Kraft pulp is often, but not always the most expensive of the three components, whereas filler/coating is often the least costly on an incremental cash cost basis. Strictly speaking, the economic impact of reducing percent SWK depends on how an incremental change in percent SWK influences the balance of mechanical pulp and filler for a given set of paper properties (gloss, brightness, etc.). If a decrease in percent SWK is accompanied by a decrease in the ratio of filler to mechanical pulp, then reducing SWK content may not be indicated if mechanical pulp is expensive and filler (coating) is cheap. Nevertheless, in the majority of cases it makes economic sense not to use more SWK than necessary.

Operating costs depend on whether a mill’s kraft supply is integrated or purchased. In mills with integrated SWK production, reducing the SWK content of SCA/LWC is normally advantageous as long as the displaced SWK can be converted to another product, such as market pulp, board or freesheet. In this case, the value of the kraft displaced is taken at the opportunity cost - i.e. the real value of the kraft resulting from a marginal increase in the sale of the other SWK-containing product. In publication paper mills that do not produce SWK on-site, kraft pulp consumption contributes significantly to operating cost.

TECHNOLOGY CONSIDERATIONS

The evolution of TMP in the 1970’s gave rise to coining of the term, “mono-furnish”, meaning a pulp with both sufficient strength and adequate optical/printing characteristics to meet the papermaker’s needs without resort to additional furnish components. The “mono-furnish” concept became industry standard for newsprint in the 1980’s (i.e. TMP or DIP), but its application to grades like SCA/LWC was hindered by the following factors:

• SCA/LWC have stringent surface flatness requirements related to printing and/or coating. Mechanical pulps have been implicated in surface quality issues such as fibre rising, smoothness limitations and gloss limitations. The “traditional” approach to preventing surface quality problems has been to reduce the long fibre content of the mechanical pulp by post-refining, which solves the problem but also limits the strength contribution of the mechanical pulp and increases SWK demand.

• SCA/LWC furnish strength requirements may be influenced by demanding downstream processes such as blade coating, in which the sheet is rewetted by coating and then drawn over a coating doctor. Supercalendering and re-realing (i.e. off-machine coating or supercalendering) also place strength demands on the sheet that may only be met by SWK.

• SCA/LWC involve furnish strength issues relating to ash content. Since ash, whether present as coating or filler, does not bear load in the sheet structure, the pulp must exhibit enough strength to satisfy the strength demands of the mixed furnish. Ash content and SWK content go hand in hand in most operations.

The role of SWK always comes down to contributing network strength through long, strong, flexible, collapsible, bondable fibres.

Several advances in process technology in recent years have helped to alleviate the above limitations and move toward the “mono-furnish” concept for SCA/LWC. These include:

1. Changes in mechanical pulping process design to achieve high pulp strength, with long fibre quality good enough to permit substitution of
long mechanical pulp fibre for SWK without surface quality problems.

2. Changes in papermaking, coating and supercalendering technology that have reduced demands on web strength (e.g., improved sheet transfer technology, shoe press, on-line contour or offset coating, on-line hot supercalendering, etc.).

Table I outlines some individual aspects of process design that have an impact on reinforcing fibre usage. Mills that make SCA/LWC with technology in the center-left-hand column of Table I are less constrained by factors that traditionally drive SWK content. Recent mill experience has shown that SCA can be made with low or zero SWK. Given this success with SCA and the current state of coating technology, it appears that we may also expect low or zero percent SWK in LWC soon.

Most mills currently in operation worldwide do not fall into the center-left column of Table I. The question remains in any given operation whether there are factors that can be managed to minimize SWK usage. Although it is not possible to generalize, measures can often be taken to minimize SWK, especially when the percent mechanical pulp allowable in the furnish is limited by mechanical pulp quality. These measures normally include, but are not limited to, mechanical pulp mill optimization.

Mechanical Pulping Process Considerations

To minimize the percent SWK in a papermaking furnish, it is necessary to shift the onus for providing network strength from SWK fibres to mechanical pulp long fibre. Although mechanical pulp fibres can replace kraft pulp fibres to an extent, long mechanical pulp fibres may, if properly processed, become implicated in paper surface quality issues as fibre rising.

Fibre rising is a paper surface quality problem that appears as sheet roughening after the re-humidification of the sheet in offset printing or in coating. Mechanical pulp fibres are implicated in this problem by virtue of the fact that they may retain their flexural stiffness since they do not fully collapse when dried. A whole, unfractured mechanical pulp fibre may be bent and held in place in the sheet surface in pressing and calendaring, but when the sheet is re-moisturized, the humidity weakens fibre bonds near the sheet surface, the bent fibres break these bonds and straighten. This adversely affects the sheet surface.

Chemical pulp fibres, on the other hand, collapse when dried and lose their ability to carry bending stress — once they conform in the sheet structure they don’t retain any memory of their previous shape or configuration. Since they don’t carry bending stress, re-moisturizing the sheet surface doesn’t cause fibre rising.

Except for the risk to paper quality posed by the mechanical pulp long fibre fraction, there are no other general quality disadvantages with respect to printability caused by mechanical pulps in LWC/SCA. With the reduction of SWK, the amount of fines and middle fraction in the furnish increases (i.e., as a consequence of more mechanical pulp) which benefits properties like formation, porosity, Scott Bond, etc. Nevertheless, in any given mechanical pulping operation fibre coarseness reduction improves fibre collapse and fibre flexibility because coarseness reduction occurs via peeling of the fibre wall and this reduces fibre wall thickness. Figure 1, reproduced from [8], shows an SEM photograph depicting the unravelling of a fibre by refining. This picture provides some insight into how fibre coarseness reduction may promote fibre flexibility and conformability.

Fibre coarseness is defined as weight per unit fibre length. Two fibres, one with high fibre diameter and low wall thickness and the other with low fibre diameter and high wall thickness can be of equal coarseness while exhibiting widely differing papermaking characteristics. Therefore, coarseness does not relate uniquely to long fibre quality as measured by collapse or flexibility. Nevertheless, in any given mechanical pulping operation fibre coarseness reduction improves fibre collapse and fibre flexibility because coarseness reduction occurs via peeling of the fibre wall and this reduces fibre wall thickness.

The challenge of mechanical pulping for SCA/LWC is to make mechanical pulp so that the long fibre component becomes a possible replacement for SWK. The middle fibre and fines components must be sufficient in quantity and well developed for good printability. The design of the mechanical pulping plant should consider the following general principles:

1. Stiff long fibres inhibit web consolidation and adversely affect sheet surface characteristics [1,2,3,4]. Once the raw material is specified and the process selected (i.e. TMP, SGW, PGW), fibre stiffness is related mainly to fibre wall thickness. High consistency refining reduces fibre wall thickness by peeling away outer layers of fibre wall. [5]. The key to long fibre quality is therefore long fibre refining.

2. Well developed middle fibre and fines fractions are necessary to achieve good web consolidation and to promote properties such as smoothness, Scott bond, porosity and opacity [4,6,7,8]. The parts of the process in which these properties can be improved are main-line refining and hydrocyclones.

3. Fine slotted screens can separate long fibre on the basis of fibre coarseness [9], but they do not improve the quality of the middle or fines fraction. Hydrocyclones fractionate the whole pulp, including fines and middle fibre fraction, since they separate according to specific surface area (i.e. bonding ability).

Mechanical Pulping Process Considerations

<table>
<thead>
<tr>
<th>Item</th>
<th>Impact on SWK Consumption</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Pulping process for non-kraft component</td>
<td>TMP</td>
<td>SGW</td>
</tr>
<tr>
<td>Choice of raw material for non-kraft component</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Design of sheet transverse pulp machine</td>
<td>Drawn to transform</td>
<td>Long span draw</td>
</tr>
<tr>
<td>Press design</td>
<td>Shoe press</td>
<td>Open mill press</td>
</tr>
<tr>
<td>Coater on-machine or off-machine</td>
<td>On-machine coating</td>
<td>Off-machine coating</td>
</tr>
<tr>
<td>Coater design</td>
<td>Film coater</td>
<td>Blade coater</td>
</tr>
<tr>
<td>Supercalender co-machine or off-machine</td>
<td>On-machine supercalender</td>
<td>Off-machine supercalender</td>
</tr>
<tr>
<td>Calendar</td>
<td>Hot roll supercalender</td>
<td>Conventional supercalender</td>
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<tr>
<th>Item</th>
<th>Impact on SWK Consumption</th>
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FIG. 1. SEM photo showing exposure and disruption of the S2 layer (Ref. 5).
paper quality, the mechanical pulping process should be designed to deliver printability by managing both the fibre length and the coarseness distribution of the finished pulp. High consistency refining reduces fibre coarseness. Nevertheless, refining is a statistical process, meaning that not all fibres receive the same energy because not all fibres spend the same amount of time in the refiner. For this reason, some coarse fibres escape from the refiners. The screening and cleaning system, as discussed below, must be designed to reject on the basis of fibre coarseness, sending high coarseness material to rejects refining. The application of elevated specific energy in two stages of rejects refining reduces the fibre coarseness while minimizing fibre breakage, so that only highly refined fibres are allowed forward and printability is preserved.

In North America, the most recently installed plants are TMP equipped with three-stage main-line high consistency refining designed for low refining intensity. The main-line pulp is screened, and in some cases cleaned, with the rejects from both systems being directed to two-stage series high consistency rejects refining. Some mills add sodium sulphite to the wood chips to improve long fibre content and reduce shive content of the TMP.

### TABLE II. TMP pilot plant results on northeastern softwood (Data from Ref. 10).

<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Process A</th>
<th>Process B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main-Line Refining</td>
<td></td>
<td>Three Stage</td>
<td>Two Stage</td>
</tr>
<tr>
<td>Screen Rejets % of total prod.</td>
<td>51</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Rejects Refining</td>
<td></td>
<td>One Stage</td>
<td>Two Stage</td>
</tr>
<tr>
<td>Total Specific Energy</td>
<td>kWh/1000MT</td>
<td>3747</td>
<td>2941 2895 2009 2497 2661</td>
</tr>
<tr>
<td>Freeness, CSF (nm)</td>
<td>53</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>Long Fiber (244-429)</td>
<td>%</td>
<td>28</td>
<td>25.6 26 22.7 26.5 27.7</td>
</tr>
<tr>
<td>Fines (P200)</td>
<td>%</td>
<td>31.5</td>
<td>35.4 33.7 33.7 31.0 12.1</td>
</tr>
</tbody>
</table>

### SCREENING AND CLEANING

The screening/cleaning system is central to the issue of minimizing SWK and since screens remove long fibre selectively, the pulp screening system is critical. Cleaners separate on the basis of fibre bonding ability (i.e. specific surface area) and are installed in the process for reasons not limited to long fibre quality. So while they may have an impact on SWK consumption, the balancing of screen versus cleaner rejects rates depends on factors other than long fibre quality.

The objective in screening should be to perform a separation based on long fibre flexibility, that is, to accept long flexible fibres and reject long stiff fibres. The ability to do this separation is important in two ways:

1. When the screen accepts only flexible long fibre, paper surface quality is protected.
2. When the screen rejects all coarse, thick-walled material, the rejects refining is focused on the fraction most in need of refining.

The use of fine slotted screens to perform the type of fractionation described above has been demonstrated by Ämälä [9]. Fractionation is seen to improve with narrower slots, lower basket profile (i.e. smoother inner basket surface) and lower passing velocity (i.e. screen size). Ämälä's results combined with...
those of others [11,12] strongly suggest that this factor needs to be considered in mechanical pulp mill design and optimization.

OTHER ASPECTS

Some other issues that may affect SWK consumption are outlined in Table III. This table is not exhaustive, but gives some examples of factors in kraft re-pulping, refining, etc. that impact on the issue.

As an example from Table III, consider the impact of pulp process instability on machine efficiency. Although the relationship between process instability and machine efficiency is often difficult to quantify, most would not doubt the existence of such a relationship.

Figure 3 depicts the results of mill data analysis for a paper machine making uncoated, surface sized fine paper from a mixture of hardwood bleached chemimechanical pulp, filler and purchased SWK. The open diamonds refer to periods when the paper machine ash retention was relatively less aggressive, whereas the solid squares are for periods when ash retention was more aggressive. The paper machine was an open draw fourdrinier, and during the period in question, paper machine efficiency was mediocre.

The data analysis depicted in Fig. 3 was based on six consecutive months of mill data. The X-axis gives a measure of pulping process instability. The Instability Index for burst was defined as the standard deviation divided by the average value (expressed as %). Each data point corresponds to a 48 hour period, with the Instability Index based on averaging of 20 values of burst. Each 48 hour period, corresponding to one data point, was selected so as to be free of grade change or change in any other key operating parameter. The 48 hour data collection period was selected so that the lag time between the pulp mill and paper machine could be ignored. Using this approach, it was possible to relate pulp quality and pulp mill stability to paper quality and paper machine operation.

The results in Fig. 3 show that the paper machine experienced greater frequency of web breaks when pulp mill stability was poor. The data further suggest that web break frequency was affected by wet-end chemistry, with more aggressive ash retention resulting in greater susceptibility to web breaks.

Figure 4 shows that higher pulp instability index was generally associated with higher percent SWK in the paper. This relationship appears to indicate that whenever this pulp mill got into problems, the paper machine would begin to break more frequently. To recover control over the machine operation the paper machine operators would add more SWK. Hence, in this case there was a clear relationship between pulp mill instability and SWK consumption and that relationship could be used to calculate the cost of that instability.

CONCLUDING REMARKS

As discussed in this paper, several factors influence SWK consumption in publication paper mills, including pulping and paper-making technology, process design and mill operation. Mechanical pulp long fibre quality plays a central role in this issue, with the principal limitation being printability. While mechanical pulp long fibre quality certainly has an important influence on printability, the quality (i.e. specific surface area) of the middle and fines fractions impacts sheet surface quality for any pulp with a given percent and quality of long fibre. Through their influence on printability, these shorter fibre fractions can be argued to have an indirect but important impact on the SWK consumption issue. Therefore, like so many other aspects of this industry, this issue is complex and multifaceted with no single clear solution.

LITERATURE

11. HAUKKALA, P., ROBINSON, D., NERG, LIIMATAINEN, H. Advanced Screening Concepts of Different Pressure Groundwood Pulps for High Quality Printing
Résumé: Le présent article discute des problèmes de technique et de procédé ayant une influence sur la consommation de pâte kraft de résineux dans les usines de papier impression à base de pâte mécanique. Les récents développements en rapport avec la mise en pâte et la fabrication du papier ont permis de réduire ou d'éliminer la pâte kraft de résineux de certaines compositions de fabrication. Les usines qui emploient des technologies davantage « établies » devraient être au courant des facteurs qui permettent aux usines plus « récentes » de contourner les règles établies en rapport avec les exigences concernant la pâte kraft. L'article donne aussi un aperçu des exigences techniques pour réduire la teneur en pâte kraft des compositions de fabrication, ce qui aide habituellement à réduire les coûts d'exploitation.


Keywords: KRAFT PULPS, SOFTWOODS, REINFORCEMENT, DECREMENTS, MECHANICAL PAPERS, PRINTING PAPERS, OPERATING COSTS