Mills Boost Production, Cut Fiber Cost By Cooking to Optimum Kappa Levels

Higher kappa numbers are allowing some kraft mills to increase pulp yield and gain recovery boiler capacity without new investments or negatively affecting pulp quality.

By Ken Patrick, Editorial Director

Today's pulp and paper mills operate under unrelenting pressure to reduce production costs. Per ton of production, the major day-to-day cost factor for chemical pulp continues to be fiber, followed by labor, maintenance, energy, and chemicals, not necessarily in that order depending on the mill and specific grade.

Appearing to have plateaued in recent years, the cost of wood rose steadily through the 1980s, 1990s, and into the twenty first century. At the same time, other chemical pulping costs progressively increased due to a variety of factors and driving forces, not the least being new environmental regulations.

Passage of the U.S. EPA's Cluster Rules in late 1997, for example, drove a stake into the heart of "elemental" chlorine based bleaching and officially ushered in the era of chlorine dioxide bleaching. More environmentally friendly ClO_2 bleaching, however, came with a higher price tag than the relatively cheap and highly effective chlorine based technologies it would replace.

To reduce rising costs in the bleach plant, many mills in the 1980s and 1990s began cooking to lower kappa numbers, often using modified cooking technologies, oxygen delignification, digester additives such as anthraquinone and polysulfide, and even enzyme delignification. But while cooking to lower kappa numbers did reduce direct bleaching costs, it also greatly decreased pulp yield. It additionally increased the solids load to a mill's chemical recovery boiler.

Confronted with the dilemma of reducing bleaching costs or maintaining yield, many mills opted for the former mainly because bleach plant costs could be more readily and accurately measured. Exact wood costs per ton of production were not so easily determined.

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However, as the cost of wood has persistently risen to an all-time high, some mills more recently have "revisited" this dilemma and are now finding that increasing pulp yield by cooking to higher kappa numbers in many cases easily offsets any associated increase in bleach plant costs. This is particularly true as techniques for measuring direct wood costs have improved.

This apparent trend in the "opposite direction" is basically a "business decision," says Fred Clark, director, technical marketing, Eka Chemicals, Pulp and Paper, North America. "It's really just getting back to the basics that have been around for a long time."

Business Decision. Clark notes that today wood fiber represents almost half (in some cases more than half) the cost of manufacturing a ton of chemical pulp, which obviously represents a significant "opportunity" for cost reduction. There's been a "cultural change" of sorts in recent years, he adds, with mills looking more at the "big picture," seeking an optimum balance between pulp yield, bleaching costs, and pulp quality.

According to Daniel Connell, senior process engineer, technical marketing at Eka Chemicals, Pulp and Paper,

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North America, technologies such as MCC, EMCC, solids profiling, oxygen delignification, lower active alkali charges, etc., allowed mills to cook to much lower kappa numbers without losing pulp strength. Or, conversely, these technologies could be used to boost yield 1%-4% while maintaining the same kappa number. Today, cooking to higher kappa numbers can take those yield credits even further, typically to the tune of 0.2%-0.4% per kappa unit, according to recent research studies.

As Connell points out, ongoing Eka studies as well as literature reports show that screened yields can range from around 40% at a kappa number of 10 to near 60% for kappa numbers above 40, varying widely by softwood and hardwood types. At the same time, studies show that cooking to higher/optimum kappa numbers can actually improve properties such as bulk, stiffness, viscosity, etc. using today's highly selective, refined ClO_2-based bleach plants, whereas in the "old days" chlorine bleaching would most likely lower these critical properties.

Eka's studies further show that while more ClO_2 per ton of pulp is generally required to bleach brownstock fiber as kappa numbers increase, especially at 90% ISO and higher (see Figure 1), the relative costs when wood is factored in drop significantly at ISO brightnesses below 90%, as shown in Figure 2.

"For some mills, going to optimum kappa cooking to increase yield and boost operating efficiencies is a win-win situation in its truest sense," Clark emphasizes. "It not only allows a dramatic reduction in operating costs, but fits well with the industry's focus on forest sustainability by getting the most out of the wood resources that are available to us. The high cost of wood fiber has been a key factor in the lack of greenfield mills in North America, and is a key reason behind some of the high-valued wood asset sell-offs in recent years."

Figure 1. Total chlorine dioxide required to bleach kraft pulps to various market brightnesses (softwood D(EPO)DP).

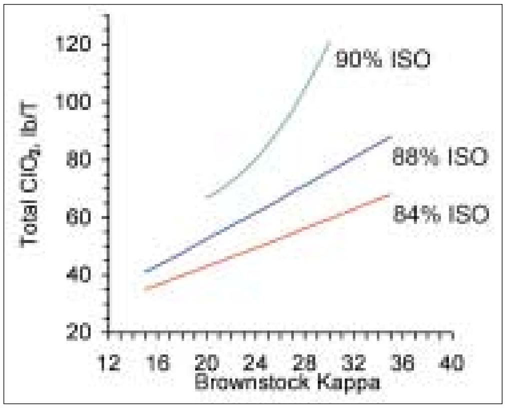

Figure 2. Balancing of variable cost components of pulp into the bleach plant.

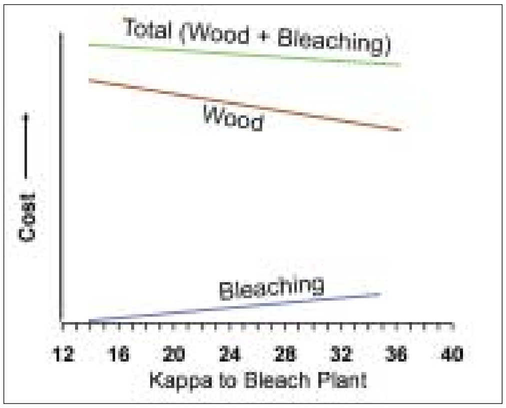

Table 1 below showing typical softwood pulping and bleaching costs was put together by Connell using \$40/green ton for wood, \$0.50/lb for ClO_2, and \$0.30/lb for H_2O_2. He notes that O_2 delignified pulps would have an even better opportunity to take advantage of the kappa-yield relationship shown in the table. The throughput increase in this table assumes that the recovery cycle is the limiting unit at the mill and that the digester plus brownstock washing can take a higher load.

The key to any kappa adjustment by a mill is careful balancing, Clark explains—"finding the optimum." Cooking to higher kappa numbers, however, might not be the best move for some mills, including certain hardwood pulps where

DIGESTER KAPPA	BLEACHED YIELD	BLEACHING COST ($)	WOOD: PULP	WOOD: COST ($)	TOTAL COST ($)	THROUGHPUT INCREASE
20	43.8	32	4.6	183	215	—
28	46.4	38	4.3	172	210	10%
34	48.4	44	4.1	165	209	20%

Table 1. Typical Softwood Pulping and Bleaching Costs

there could be a limitation based on rejects. But modified cooking processes such as MCC, EMCC, RDH, etc., typically reduce rejects rates, allowing softwood pulps above 40 kappa out of the digester without any significant rejects, depending on furnish, chip quality, and specific cooking processes.

"We're finding that, in regard to rejects, softwood kraft mills using EMCC and Lo-solids cooking generally have a lot more flexibility than they had with conventional cooking. One softwood pulp mill superintendent told us he could go up to 40-plus kappa before beginning to see any increase at all in rejects. On the other hand, some hardwood mills report reject limitations beginning at maybe 16 kappa, while others report a threshold nearer 20 kappa," Connell explains.

"In North America, some softwood pulp mills are running kappa numbers in the high 20s or low 30s, while many others are running in the low 20s with no oxygen delignification," Connell continues. "The latter, especially, have an opportunity to boost yield and gain recovery boiler capacity."

Clark points out that mills with oxygen delignification stages should, of course, continue to use them in going to an optimum kappa scenario. "Significant capital has already been spent for these stages, which can provide some technical advantages. It's a matter of understanding limitations and balancing and distributing work between the digester and O_2 reactors. Trying to do everything in the digester can quickly lead to a flat portion of the curve. It's like shifting gears, technically," he says.

Recovery Boiler Benefits. One major limitation in the chemical pulp industry today is the recovery boiler, Clark notes. Cooking to optimum kappa levels can help reduce solids loads to the boiler, which represents a significant opportunity for increased production, especially for mills that are boiler-capacity limited, he explains.

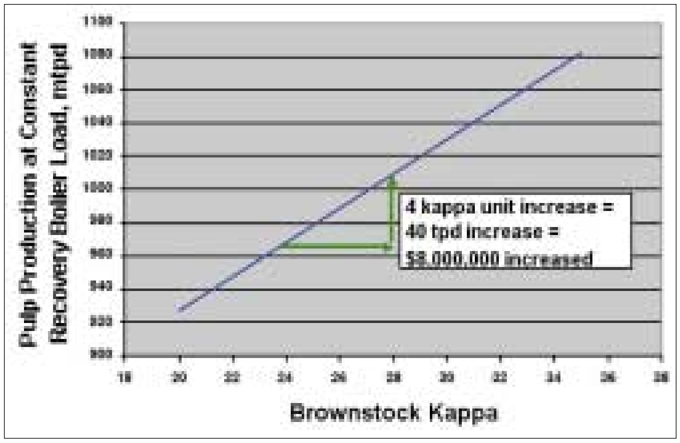

Figure 3. Effect of increased kappa on pulp production and related revenues.

As shown in Figure 3, an increase in kappa of four points (from 24 – 28) can boost production by 40 metric tpd. As Connell explains, assuming $600/metric ton for NBSK and 350 operating days per year, the resulting annual revenue increase is $8,000,000-plus.

Table 2 below was put together by Connell based on the Fisher International database. It presents scenarios of North American recovery boilers at bleached pulp mills operating at higher kappa loads and the projected impact on solids loading and boiler utilization rates.

"I used the rated capacity of these boilers and did some general, rough estimating of their solids loading at projected NA bleached pulp production levels for 2010," Connell explains. "The resulting rough estimate for average recovery boiler utilization (accounting for only boilers installed in 1970 or later) in North America was, accordingly, 94%.

I then took this to a higher kappa scenario, using an average increase of 3 kappa points for softwood and 1 - 2 points for hardwood. "This offloads recovery boilers such that the

REGION	STATED CAPACITY, MTPY SOLIDS	1970 OR NEWER CAPACITY, MTPY SOLIDS	PROJECTED 2010 SOLIDS LOADING NO KAPPA INCREASE		PROJECTED 2010 SOLIDS LOADING KAPPA INCREASE	
			MTPY Solids	Utilization	MTPY Solids	Utilization
SE U.S.	38.1	30.2	28.2	93%	27.3	90%
NW U.S. and W. Canada	20.9	15.4	14.0	91%	13.3	87%
NE U.S. and E. Canada	15.1	10.9	11.6	106%	11.1	102%
MidAtlantic U.S.	7.4	5.9	5.3	89%	5.0	84%
MidWest U.S.	4.2	4.2	3.8	91%	3.6	87%
Total	**85.7**	**66.6**	**62.8**	**94%**	**60.3**	**91%**

* Utilization based on % of 1970 or newer capacity

Table 2. Impact of higher kappa cooking on solids loadings of North American recovery boilers at bleached kraft sites.

average utilization rate drops to roughly 91%. Connell emphasizes.

European/Scandinavian Perspective. Prof. Jiri Basta, Akzo/Eka Fellow, Eka Chemicals AB, Sweden, reports that some mills in Europe and Scandinavia have experienced more produced tons from the same equipment, less wood required, debottlenecking of the recovery area, and better digester and O_2 delignification control possibilities when cooking to higher kappa numbers.

As in North America, Basta stresses that optimum kappa cooking is basically "a proper balancing of unit operations in pulp production." He adds that the "concept is about increasing 'real' productivity without any substantially increased investment, while keeping pulp and effluent quality parameters at acceptable levels."

Both mill and laboratory experiences, Basta notes, show that an increase in yield will also reduce beating energy, increase tensile index, etc. "As one European mill expressed it, 'we did not get any new customers due to higher kappa cooking, but we could send more pulp to the same customer base with no complaints about pulp quality. Moreover, we did not need to ask our bosses for additional investment,'" he adds.

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Depending on the changing prices of wood and pulp, yield increases from cooking to higher kappa values can be taken as wood savings or increased production. "In special cases, you can do both," Basta says.

As both Clark and Connell also point out, unbleached mills, as well, can benefit from higher kappa cooking. Some European unbleached sack paper and linerboard mills have increased their kappa numbers from 40 - 45 to near 60 and have experienced a yield increase of about 3% as well as a significant decrease in dry solids loading to their recovery boilers, Basta says.

TYPE OF FACILITY	KAPPA NUMBER AFTER COOKING		
MODERN SOFTWOOD KRAFT MILL	**20**	**28**	**35**
Active Alkali Charge on BD Wood, % as NaOH (EA)	25.7	24.0	22.1
Total Yield in Cooking, %	45.3	47.3	48.8
Dry Solids to Recovery, mtpd	1827	1828	1828
Dry Solids to Recovery, mt/mbdt pulp	1.97	1.81	1.69
Pulp Production, mbdt/d	928	1008	1083
MODERN EUCALYPTUS KRAFT MILL	**12**	**16**	**20**
Active Alkali Charge on BD Wood, % as NaOH (EA)	19.4	18.8	16.0
Total Yield in Cooking, %	51.3	53.5	55.1
Dry Solids to Recovery, mtpd	1999	2000	1999
Dry Solids to Recovery, mt/mbdt pulp	1.67	1.34	1.23
Pulp Production, mbdt/d	1198	1497	1626

Table 3. Process data, pulp production, and dry solids to recovery at different cooking kappa levels.

Table 3, based on work at Helsinki University of Technology using advanced simulation tools, reflects ongoing, broad scope kappa number testing by Eka Chemicals covering the continuous digester, recovery boiler, caustization, evaporation plant, washing, screening, and bleaching. As the table shows, an increase of 5 kappa units with softwood can boost production some 50 metric tons of "extra" pulp per day, which has been verified in actual mill situations, according to Basta. In the lower part of the table, the same kappa number increase with eucalyptus indicates an even greater boost in production.

Basta explains that the vast majority of mills in Scandinavia and most mills in Europe have O_2 delignification. "This can give a mill an additional degree of freedom—to decrease the degree of cooking or to increase the kappa number reduction in the oxygen stage.

"However," he adds, "it is not so easy to extend the kappa number reduction much above 50% in a single vessel in a selective way. Moreover, since the effluents from cooking and oxygen delignification are going to the same recovery boiler, an excess in dry solids with low heating value may hinder a mill from increasing the production rate. Therefore, in most mills applying the optimum kappa cooking concept, there is an increase in the kappa number prior to bleaching," Basta reports.