

Enhancing yield through high-kappa pulping

PETER W. HART

ABSTRACT: Chemical pulping consists of a collection of delignification reactions designed to remove amorphous lignin from the fiber matrix while preserving carbohydrates in a fibrous form. Commercially available cooking processes are relatively nonselective with reagents attaching both lignin and carbohydrates. Generally, the carbohydrates react more slowly than the lignin, so some carbohydrate selectivity does exist for modern pulping processes. However, extended reaction times or excessive reaction temperatures will substantially reduce pulp yield. To date, only a few methods of converting high-kappa pulp into enhanced fiber yield have been demonstrated.

Application: Research gaps need to be filled to fully implement an enhanced-yield kraft pulping process.

Typically, for bleachable-grade fiber, chemical pulping has to be conducted to around kappa no. 30 (a measure of the residual lignin content, or bleachability) for softwoods and kappa no. 20 for hardwood species to successfully liberate fibers from the wood matrix [1]. High-yield brown pulping, especially for softwood grades, typically stops pulping reactions at much higher kappa numbers and employs various refining processes (hot stock, low consistency refining, or high consistency refining) to liberate fiber from the wood matrix. For linerboard production, pulping is routinely stopped at kappa no. 90-110 while sack-grade fiber is routinely produced at kappa no. 50-80 [2]. In recent years, the trend in bleachable-grade chemical pulping has been to push the kappa numbers below the fiber liberation point. The reason has been to reduce the environmental impact associated with bleach plant effluents [3].

Lower kappa-number pulping has two main limitations. The first is that pulping to lower kappa numbers can potentially damage pulp strength [4]. The second is that, as delignification enters the residual pulping phase, the rate of carbohydrate dissolution becomes faster than the rate of delignification, resulting in a substantial loss in pulp yield [5]. In general, delignification reactions that occur during the pulping process or in oxygen delignification do not contribute toward effluent loading. This is because the organic fraction removed from the wood matrix is recovered through brownstock washing and sent to the recovery boiler to be converted into energy through combustion. Typically, delignification processes that occur during bleaching are not recovered for combustion due to the presence of chlorides in the effluent [6].

One of the main reasons that chemical pulping has traditionally targeted pulping to at least the fiber liberation point is that reject and shive production in the resulting pulp increases substantially when pulping is stopped above the fiber

liberation point. This results in a direct loss of usable fiber, and the practice of recycling and recocking these rejects does not improve pulp yield [8].

To date, only a few methods of converting high-kappa pulp into enhanced fiber yield have been demonstrated. Johakimu [9] gives an excellent recent literature review of high-yield pulping technologies and influencing factors. He discusses recognized digester modifications such as polysulfide, anthraquinone (AQ), neutral sulfite semichemical pulping, post-kraft oxygen, and recent alkaline peroxide mechanical pulping (APMP) technologies. Some of these methods have been shown to work for bleached fiber. Polysulfide and AQ have been used commercially for several years. Unfortunately, the yield gains obtained with these chemical modifications to the cooking process are at best moderate [10,11] and are not considered to be breakthrough technology [12]. The APMP process produces brightened fiber with substantial yield improvements, but the strength properties are not comparable to fully bleached kraft pulp fiber [13].

Two methods have been demonstrated to meet the yield and strength criteria required for breakthrough technology. One method involves pulping to a high kappa number and performing multistage aggressive oxygen delignification to further reduce the kappa number to traditional bleachable grade levels. This is done in an alkaline environment, and pulping chemicals can be recovered through the recovery boiler cycle. Laboratory-scale trials have suggested that fully bleached pulp yield improvements of 4-6 points may be realized through application of double-oxygen technology in conjunction with high-kappa pulping [14-17].

The other method involves separating hardwood kraft rejects, processing them through high-consistency refining in the presence of alkaline peroxide, recombining the treated rejects with the primary screened accepts, and subjecting the combined stream to a mild oxygen delignification treatment

to about kappa no. 30. The high-kappa hardwood pulp is then treated with enzymes and bleached in a traditional elemental chlorine-free bleach plant. Pilot-plant trials have suggested that an increase in fully bleached pulp yield of about 6-8 points may be realized through this process [18,19]. Bleached pulps using this method exhibit equivalent or better strength properties compared to fully bleached, traditional-kappa hardwood kraft pulps.

Johakimu [9] has cited references from Jarkko [20] demonstrating an APMP mechanical pulping process for birch; no data were presented for softwoods [20]. The APMP process produces reasonably bright (80+ ISO) fiber at extremely high yields. Unfortunately, the strength properties of the resulting brightened fiber is substantially inferior to fully bleached kraft pulp fiber [13]. Variations upon APMP technology have been patented by industry researchers [21-24].

Potential commercialization barriers exist for both breakthrough methods discussed previously. In addition to lost strength properties resulting from refining of the high-kappa pulp ahead of the oxygen stages, capital expense is a major barrier for multistage oxygen delignification. For the rejects separation and partial treatment method, bleach plant effluent loading is a major constraint on commercial implementation for bleachable-grade pulps. The rejects separation method has been successfully employed commercially in a high-yield brown mill in Brazil.

OPPORTUNITIES FOR FURTHER RESEARCH

Two potential pathways for development of these breakthrough technologies exist. Their selection will be dependent on the mill grade structure (unbleached to bleached paper and paperboard grades). To date, the rejects separation process method has demonstrated a slightly improved yield performance for hardwood and eucalyptus pulps over the enhanced oxygen delignification performance method. Significant yield gains have been reported for softwood pulps subjected to the rejects separation process. However, no suitable bleaching mechanism has been devised to reduce the higher-kappa bleaching cost to near-traditional levels. Alternative, lower-cost bleaching options need to be developed for the high kappa number softwood fiber. These enhanced methods need to produce high-brightness pulp without negatively impacting pulp yield or intrinsic fiber strength. In addition, research efforts for both hardwood and softwood pulps are needed to determine potential methods to collect and treat bleach plant effluent from the higher-kappa brownstock being sent to the bleach plant via this method.

For the high-selectivity oxygen delignification method, research efforts on non-chlorine-containing methods for activating lignin toward oxygen need to be performed [25]. In addition, improved methods of transporting oxygen into high-kappa number fiber bundles without hurting fiber strength should be investigated.

To date, the higher-kappa pulping processes for both high-kappa double-oxygen work and for the rejects separation method have been performed with typical, commercially available hardwood and softwood chips. The impact of pulping with extremely thin veneer-type chips should be investigated. Using thinner chips may potentially result in a higher percentage of liberated fibers and reduce some of the mass transfer difficulties typically associated with brightening or bleaching shives and rejects. **TJ**

LITERATURE CITED

1. Kocurek, M.J., Grace, T.M., and Malcolm, E.W. (Eds.), *Alkaline Pulping*, 3rd edn., Joint Textbook Committee of the Paper Industry, TAPPI/CPPA, Atlanta, GA, USA, 1996.
2. Kocurek, M.J., Grace, T.M., and Leask, R.A. (Eds.), *Mechanical Pulping*, 3rd edn., Joint Textbook Committee of the Paper Industry, TAPPI/CPPA, Atlanta, 1996.
3. Hart, P.W. and Santos, R.B., *TAPPI J.* 12(10): 19(2013).
4. Tichy, J. and Procter, A.R., *Sven. Papperstidn.* 84(15): R116(1981).
5. Hart, P.W. and Connell, D., *TAPPI J.* 7(7): 3(2008).
6. Hart, P.W., Gilboe, M.M., Adusei, G., et al., *TAPPI J.* 4(1): 26(2005).
7. MacLeod, M., *Pap. Puu* 89(4): 1(2007).
8. Andrews, J.D. and Hart, P.W., *TAPPI J.* 12(2): 41(2013).

ABOUT THE AUTHOR

Wood is one of the highest cost raw materials in the production of pulp and paper, so the need for enhanced pulp yield processes is paramount to the economic survival of the pulp and paper industry. Currently, there is a belief that the predominant pulping process in the world (the kraft process) has an inherent "yield barrier" due to the relative lack of selectivity in the pulping process. This work is a review of a new, enhanced-yield production method for pulping. Also identified are areas for future research needed to move this new, enhanced yield process to full commercialization. Currently, this method is only being used in a limited number of unbleached pulping processes.

The current work was produced as part of the Agenda 2020 Next Generation Pulping Subgroup. Literature and current state of the art laboratory and operating practices were determined and reviewed. Areas for future research focus were debated and determined.



Hart

Hart is director, Fiber Sciences, at MWV Corp., Atlanta, GA, USA. Email Hart at peter.hart@mwv.com.

9. Johakimu, J.K., "Investigation of potential to develop high pulp strength from high yield kraft pulp made from *Pinus patula*," M.S. thesis, University of KwaZulu-Natal, Durban, South Africa, 2007.
10. Hart, P.W. and Ransdell, J.C., *TAPPI J.* 7(3): 22(2008).
11. Jaing, J.E., *Tappi J.* 77(2): 120(1994).
12. Agenda 2020 Technology Alliance, *Forest Products Industry Technology Roadmap*. Available [Online] <http://www.agenda2020.org/technology-roadmaps.html> <14Oct2014>
13. Hart, P.W., Waite, D.M., Thibault, L., et al., *TAPPI J.* 8(5): 19(2009).
14. Parthasarathy, V., "Use of digester additives and oxygen delignification to gain bleached pulp yield and achieve environmental objectives," *Breaking Pulp Yield Barrier Symp.*, TAPPI PRESS, Atlanta, 1998, p. 219.
15. Magnotta, V., Kirkman, A., Jameel, H., et al., "High-kappa-[no.] pulping and extended oxygen delignification to increase yield," *Breaking Pulp Yield Barrier Symp.*, TAPPI PRESS, Atlanta, 1998, p. 165.
16. Bokstrom, M. and Norden, S., "Extended oxygen delignification," *Int. Pulp Bleaching Conf.*, TAPPI PRESS, Atlanta, 1998, p. 23.
17. Ragauskas, A., Lucian, L., and Jameel, H., "High selectivity oxygen delignification," U.S. Department of Energy Office of Industrial Technologies, Washington, DC, 2007.
18. Hart, P.W., Waite, D.M., Nutter, D.E., et al., Canadian pat. 2690571 (April 9, 2013); Japan pat. 5295231 (June 21, 2013).
19. Hart, P.W., *TAPPI J.* 10(9): 37(2011).
20. Jarkko, M., lecture notes on high yield pulps (mechanical and semimechanical pulping), 2005.
21. Ahrel, B., U.S. pat. 4,187,141 (Feb. 5, 1980).
22. Akerlund, S.G. and Hook, J-E., U.S. pat. 4,311,553 (Jan. 19, 1982).
23. Herkel, M., U.S. pat. 20,040,200,586 (Oct. 14, 2004).
24. Xu, E., U.S. pat. 20,140,083,633 (Sept. 27, 2013).
25. McKenzie, D.J., "The evolution of pulp bleaching practices at Harmac Pacific," *Int. Pulp Bleaching Conf.*, TAPPI PRESS, 1994, p. 163.

Maintenance Painting of Steel Structures in Pulp and Paper Mills

A Program Approach for Maximum Cost Effectiveness

**2nd
Edition**



Success and cost-effectiveness in a mill depend heavily on an ongoing program to maximize preventive maintenance of the protective coatings on the steel structures. This edition focuses on the keys to a good maintenance program with a concession to today's busy mill engineers.

Contents include:

- Scope, fundamental elements, and condition assessments
- Pulp and paper mill environments
- Surface preparation requirements and standards
- Paint systems and materials
- Quality and productivity
- Special considerations

**Updated
from 2001
Edition**

\$31 TAPPI members / \$50 non-members. Code: 0101R339

For more information go to:

www.tappi.org/maintenance-painting