Environmental Engineering and Management Journal March/April 2007, Vol.6, No.2, 169-172
http://omicron.ch.tuiasi.ro/EEMJ/

"Gh. Asachi" Technical University of Iasi, Romania

Book review

HANDBOOK OF PULP

Herbert Sixta (Editor), vol.2
Wiley-VCH Verlag GmbH& Co. KGaA, Weinheim, Germany
ISBN-10: 3-527-30999-3; ISBN-13: 978-3-527-30999-3, XXII + 744 pages.

Pulp production is a very complex but also an important economical and industrial activity. Pulp's widest usage are paper and paperboard, but there are also other applications like in textile, pharmaceutical or chemical industry, therefore pulp is a very necessary product for the modern society. As fibrous material, pulp is the result of some complex production process that involves either chemical or mechanical treatment of various types of plant material. Wood represents the most used raw material - up to 90% of world's pulp production originates from wood pulping, the remaining 10% being the result of annual plant processing.

Sixta's *Handbook of Pulp* presents the most important aspects of pulp obtaining processes. This reference book describes the pulping processes used for paper and board manufacturing, as well as waste liquor treatment, pulp bleaching and environmental aspects, while also covering pulp properties and applications.

The handbook is structured in two volumes and four parts: part I: *Chemical Pulping*, part II: *Mechanical Pulping*, Part III: *Recovered Paper and Recycled Fibers* and the part IV: *Analytical Characterization of Pulps*. The second volume includes the last chapters of part I (Chemical Pulping) and parts II, III and IV.

Pulp bleaching is largely treated in the 7-th chapter at the beginning of the volume. After the description of general principles of pulp bleaching, the bleaching reactants and the bleaching operations and equipment are briefly discussed. Due to their importance, oxygen-alkali delignification is widely analyzed. Chemistry of oxygen delignification is presented starting with the residual lignin structure and reactivity. Functional group content in residual lignin, frequency of linkages in kraft lignin and relative susceptibility of model compounds to oxygen are exemplified. The formation and stability of reactive oxygen species are discussed as well as their attack in lignin molecule. The reaction schema for oxygen delignification is presented including the reaction mechanisms involved. Due to the fact that oxygen delignification is a non-selective process, the carbohydrate reactions are included. The role of metals in the protection/degradation of cellulose is also discussed. The mass transfer of oxygen in the aqueous phase and the oxygen diffusion in the fiber wall are analyzed. Mathematical models describing the kinetics of oxygen delignification are presented and the kinetic parameters are compared with experimental data. Besides of lignin dissolution rate equations, kinetics of cellulose chain scission is also discussed. Factors affecting oxygen delignification rate are underlined, and a model to predict industrial oxygen delignification is analyzed. The process technology is largely treated due to the importance of oxygen delignification in modern bleaching plants. Since chlorine dioxide still represents the main reagent in pulp bleaching, the chlorine dioxide stage is widely treated in the volume. Properties of chlorine dioxide and its generation are presented. The reactions of chlorine dioxide with different lignin compounds are discussed. Methods of pulp bleaching involving chlorine dioxide are underlined together with environmental impact of this bleaching stage. Nonchlorine bleaching stages such as ozone and hydrogen peroxide are largely used in the pulp manufacture. These reactants are environmental friendly bleaching chemicals and used in totally chlorine-free bleaching sequences. The handbook treats both ozone and hydrogen peroxide pulp bleaching stages. The mechanism of delignification and factors affecting bleaching results are discussed for each type of these reactants. Application of ozone and hydrogen peroxide in chemical pulp bleaching is also presented. Because it is imperative for bleach plant operations to recirculate process liquors to minimize the consumption of fresh water, some consideration regarding bleach plant liquor circulation are included.

Chapter 8 of volume 2, *Pulp Purification* treats the methods used to enhance the purity of dissolving pulps. Purification processes for dissolving pulps include both the removal of noncellulose material and the change of the molecular distribution of carbohydrates. The treatment of pulp with aqueous sodium hydroxide solution represents the principal mean in producing highly purified dissolving pulps. In this respect, the handbook presents cold and hot caustic extraction processes as methods used in producing high quality pulps.

Chapter 9, *Recovery,* deals with the kraft black liquor processing. Characterization of black liquor regarding chemical composition and physical properties is presented. The composition of black liquor depends greatly on the wood species, the composition and amount of white liquor charged, the unbleached pulp yield, and the amount of recycled bleach filtrates, predominantly from oxygen delignification stage. The higher heating value of black liquor depends on its composition of dry matter. The most important physical properties which affect evaporator and recovery boiler operation include liquor viscosity, boiling point rise, surface tension, thermal conductivity and heat capacity. The stages of black liquor processing are briefly discussed: black liquor evaporation, kraft chemical recovery, white liquor preparation and lime burning.

Environmental aspects of pulp production are treated in Chapter 10. The impact of pulping and the measures to control and limit the emissions are described. Emissions in the Atmosphere, emissions to the aquatic environment and solid waste generation are issues largely discussed in the chapter. This short summary on the environmental impact of pulp production has highlighted the point that there is no simple solution to all negative impacts. The close interrelation of the different process steps makes it almost impossible to avoid one problem without raising or increasing the size of another one. An increasing knowledge of the processes will doubtless generate the potential to balance the different interest of the conservation and the intelligent use of resources, with a minimum impact on the environment at best chemical pulp quality.

An interesting chapter of the volume 2 refers to pulp properties and applications. In this chapter the main emphasis is placed on a comprehensive discussion of the physical and chemical properties of paper-grades pulp and dissolving-grade pulp, especially. A representative selection of commercial paper-grade pulps is analyzed regarding basic characteristics, extractives, alkali resistance, carbohydrates, functional groups ash, water retention value and zero-span tensile index. Numerical evaluation of molecular weight distribution of fully bleached commercial paper pulps is presented. Fiber weight factor and fiber dimensions of these pulp grades are also presented. Dissolving pulp refers to pulp of high cellulose content which is used to manufacture various cellulose-derived products such as regenerated fibers or films. The processability of dissolving pulp is characterized as its reactivity towards derivatizing chemicals or solvents. Reactivity is related to the accessibility of chemicals to the cellulose, which means the relative ease by which the hydroxyl groups of cellulose can be reached by the reactants. A characterization scheme of dissolving pulp is presented in the chapter. Chemical composition of dissolving pulps is largely treated: short-chain alkali-soluble carbohydrates, extractives and resins, residual lignin and pulp brightness, inorganic compounds. Molecular properties of cellulose material (molar mass, molar mass distribution) as functional groups are widely analyzed. Supermolecular structure of different dissolving pulp grades is discussed and their structural parameters are listed. The fibrillar morphology of pulps regarding cell wall layers architecture, distribution of non-cellulose carbohydrates across the fiber wall, pore structure and accessibility are underlined. The factors affecting degradation of dissolving pulp are presented at the end of this chapter.

Part II of the handbook, *Mechanical Pulping*, refers to the obtaining of pulp by means of mechanical processes. Mechanical pulping procedure is divided in grinding process and refining process. The chapter begins with the presentation of raw materials for mechanical pulping. Wood quality, wood log storage and debarking, and wood chipping are treated and the effect of these operations on pulp quality as well. Grinding is a thermomechanical process that is divided in two parts: softening and breakdown of the fiber structure and peeling of the softened fibers from the wood matrix in the grinding zone. Mechanical and thermal processes in grinding are presented regarding their impact on pulp quality. The role of fibers softening, fiber loosening and peeling in a grinding process are presented. The main parameters affecting the grinding process and groundwood quality are analyzed. Grinders and auxiliary equipments for mechanical pulping by grinding are also presented. A typical flow sheet of a groundwood process begins with wood logs preparation and ends with storage of groundwood pulp. The grinder is the most important machine in the process and different types of grinders are presented: ring grinder, pocket grinder, chain grinder. The characteristics and specific features of each grinder type are discussed. Due to their importance, pulp stones are treated separately. The ceramic stone structure is presented together with the characteristics of its abrasive particles. The pulp stone requires a certain surface structure to produce a certain groundwood quality. This is achieved by sharpening the pulp stone with a special device (metallic burr). Spiral burr sharpening process is of special importance on the pulp quality. A modern grinding process, pressure grinding, is treated separately due to its advantages: the pulp has a higher long-fiber content, higher strength level and optical properties of pulp improve. The refiner processes represent the modern alternative of traditional grinding. The development of the refiner processes has been enforced by much better design of the refiners, and the development of wear-resistant plate materials. There are several types of refiner pulps depending on the kind of chip pre-treatment or chip post-treatment: refiner mechanical pulp, thermo-mechanical pulp, chemithermo-mecanical pulp. The features of these processes are discussed in terms of parameters, chemicals, temperature, pressure, duration, and pulp properties. In the refining procedure, disc refiners of different construction are used. The distinctiveness between single-disc refiner, double-disc refiner and multi conical refiner are underlined. Refiner plate is the heart of the refining process. The type of refiner plate design chosen is specified for a certain pulp quality. By-directional refiner plate is standard in refiner pulp production and for this reason this plate type is presented in the chapter. Mechanical defibration of wood leads to a mixture of different fiber components and debris. Unscreened mechanical pulp contains shives, long and short fibers, and fines. Mechanical pulp screening is performed on two basic principles: pulp classification (separation of the pulp into fraction according component dimensions) and separation according particles density. This subject is discussed in the book together with the machines and aggregates for pulp screening and cleaning. The factors affecting screening efficiency depends on the following influences: parameters of the material to be screened; parameters of the screening elements; process or design parameters. All these influences are discussed in the volume. Screen types are also presented: bull screen (vibration screen) for coarse reject separation and pressure screen for screening and fractionation of mechanical pulp. General construction forms of pressure screen rotors and screen plate designs are illustrated. Some schematic examples of modern screening concepts are presented. Several considerations regarding reject treatment and heat recovery are discussed at the end of this chapter. Mechanical pulps contain almost the same lignin quantity as the wood. Lignin is the dominant source of chromophores in mechanical pulp. Bleaching of this pulp is achieved by decoloring or destruction of these compounds by means of reductive or oxidative reactants. A special chapter is dedicated to lignin-preserving bleaching of mechanical pulp. There are few reactants used on large extent to bleach mechanical pulp: sodium dithionite and hydrogen peroxide. The particularities of dithionite bleaching and hydrogen peroxide bleaching are treated in the chapter. The factors affecting brightness gain, bleached pulp properties and brightness stability are underlined.

A short chapter deals with the latency and properties of mechanical pulp. Fiber deformation in mechanical pulping (latency) occurs when fibers are defiberized al high temperatures and high consistencies. Fibers are deformed due to stresses that they encounter. Latency must be removed by pulp agitating al low consistency. Properties of mechanical pulp depend on wood species and grinding (refining) process. Mechanical pulp is characterized by fiber fractional composition, bonding ability of fiber fractions, optical properties. These aspects are discussed in the chapter. General quality requirements of mechanical pulp for use in printing paper grades are presented.

Part III entitled *Recovered Paper and Recycled Fibers* focuses on the use of recovered paper in paper production. Recovered paper has become the most important fiber raw material for paper production since the volume of recovered paper used globally in the paper industry has exceeded the total volume of virgin fiber (chemical pulp and mechanical pulp). Firstly, the European list of standard grades for recovered paper and board (EN 643) is discussed. The requirements of this standard regarding each recovered paper grade are underlined. Nonpaper components are also listed. The criteria of the naming of recovered paper and for the description of the individual recovered paper grades are presented. A comparison with recovered paper lists in North America and Japan is included. The statistical parameters used in the recovered paper processing are presented: recovered paper utilization rate; recovery (collection) rate; recycling rate. Considerations regarding each of there parameters are presented. The factors affecting the use of recovered paper in producing various paper grades are underlined. A special attention is given to the limits of recycling rate of different grades.

Chapter 5 of the part III focuses on description of the methods of recovered paper collection. Depending on the origin of collected paper a distinction exists between pre- and post-consumer recovered paper. The collection of recovered paper is accomplished by collection in private households and small enterprises, collection from industrial and business operations, return of recovered paper from converting facilities such as printing houses and corrugated board industry. For each source of recovered paper the most suitable collecting methods are presented: pick-up system, drop-of system, and curbside collection. Efficiency of these collection methods is discussed. Next chapter briefly treats on the sources of recovered paper that are classified according to the quantity of collected paper. A quantitative description of the recovered paper cycle in Europe is presented and a balance of paper, recovered paper collection and paper waste in Germany is also included. Sorting, handling and recovered paper storage are treated separately. Despite many technical developments, the sorting of recovered paper continues to be predominantly a manual, labor-intensive activity. It is stated that the amount of work involved in the manual sorting depends primarily on the origin of recovered paper. The concepts of positive and negative sorting are presented and a distinction between these sorting concepts is made. The factors influencing sorting productivity are presented. Handling strongly influences the prize of recovered paper. A distinction between loose recovered paper and baled recovered paper regarding origin of recovered paper and apparent density is made.

Due to importance, the legislation of recycled fibers use is treated in the chapter 8 of the part III. A wide range of legislation in various countries has attempted to promote material recycling and to reduce further the waste generation that requires disposal in appropriate facilities. Legislation is categorized into general regulations and special regulations relating to private households for reduction of municipal waste. European Union has adopted regulations like European Waste Guideline 91/156/EGW and EU Packaging Directive 94/62EG that have special importance. These EU documents are discussed in the chapter regarding the responsibility of the paper producers, paper consumers, and recovered paper collectors. The features of the legislation in the U.S. and Japan are also presented. At the end of the chapter, European List of Standard Grades of Recovered Paper and Board is presented.

Part IV of the second volume is entitled *Analytical Characterization of Pulps* and comprises valuable information for anybody that is working in the field. The importance of quality control in pulp and paper manufacture is underlined and exemplified at the beginning of this part. Basics of the quality control statistics and conditions for testing and conditioning are discussed. According a logical schedule, the analytical characterization begins with the determination of low molecular-weight components of the pulps: moisture, inorganic components and extractives. The most suitable methods used for its determination are briefly presented. Methods for studying the macromolecular composition of the cellulose fibers are also discussed. A special attention is given to determination of lignin content of different pulp grades. The extent of delignification which correlates with pulp lignin content, is evaluated according to well known methods: Roe number, Chlorine number, Kappa number. Cellulose and hemicelluloses differ strongly in their alkali solubility which depends on their degree of polymerization, monomer composition and degree of branching. Alkali solubility and resistance of cellulose fibers are largely used for characterization of different grades of pulp and the methods for determination are discussed. The carbohydrate composition of pulps are different depending on wood species and pulping and bleaching processes and must by determined for various reasons. The most important analysis methods of monosaccharide content are: gas chromatography, thin-layer chromatography, liquid chromatography. Determination of pentosans and uronic acids after pulp hydrolysis is also presented. The functional groups are divided in carbonyl functions and carboxyl functions. The importance and the principles of these organic functions analysis are discussed. Macroscopic properties of macromolecular compounds depend heavily on the chain length of its molecules, including their degree of polymerization. In cellulose products, the degree of polymerization also indicates how severely the native material has been degraded during cooking and bleaching. Knowing the degree of polymerization is of special importance for obtaining a high quality pulp. Handbook contains valuable information regarding the methods to determine molecular mass and molecular mass distribution. A survey of these methods is presented and the special features of each method are underlined. The specific properties measured as: osmotic pressure, light scattering, sedimentation rate, retention time in a permeated gel and solution viscosity are described. A comparison between different methods for molecular mass determination is also included.

Special attention is given to the characterization of supermolecular structure of cellulose. Methods for determination of degree of crystallinity (X-ray diffraction, solid-phase NMR spectroscopy, densitometry and reaction kinetics) are discussed. Cellulose fibers are a multi-phase body. Accesibility of cellulose molecules toward liquids is a key factor for monitoring the swelling properties and chemical reactivity of pulps. The porosity of the fiber cell wall plays an important role in chemical processing of pulp. Accessible surface area of fibers is another parameter influencing chemical behavior of fibers. A discussion of the methods for determination of fiber porosity and accessible surface area is included. The behavior of cellulose when is exposed to moisture and the role of the bound and free water are issues treated in the handbook. In a logical succession, the morphological features of pulp fibers are revealed, starting with the identification of fibers origin. Techniques applied for preparing samples and visualization them are discussed. A selection of staining methods used for fiber identification using visible and UV microscopy is given. Scanning electron microscopy (SEM) is recommended as a very valuable tool in the study of detailed fiber morphology, for example examining the structure of tracheids and vessels, and the dimensions of cell wall and cell wall layers, pits and fenestrations. From the point of view of the papermaker, the fiber dimensions are the most important characteristic. Fiber length and width determination is performed in all paper mills. Fiber parameters as: contour length, curl, dimension of cross section, thickness of fiber wall, fiber volume, coarseness are frequently determined in the paper mill laboratories. The mechanical properties of a single fiber and of wet and dry fibers are also specified. The last chapter deals with the papermaking properties of pulps. In a concise manner, pulp beating and drainage resistance of pulp are commented.

Handbook of Pulp edited by Herbert Sixta addresses to specialists working in the field of pulp and paper and represents an especially valuable scientific and technological support. Based on very rich bibliographical references, the volume is obviously an exceptionally valuable tool for specialist in the field, researchers, teachers and students for enlarging their horizon on pulp manufacturing. The excellent index of the handbook puts it in light as valuable and comprehensive resource of information, which might be an indispensable and powerful tool for both educational and practical reasons.

Adrian Catalin Puitel
Alina Mihaela Bordeianu
Dan Gavrilescu
Department of Paper Engineering
Faculty of Chemical Engineering
Technical University Iasi, Romania