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Book review

HANDBOOK OF PULP

Herbert Sixta (Editor), vol.1
Wiley-VCH Verlag GmbH& Co. KGaA, Weinheim, Germany
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Pulp production represents a complex and an important economical and industrial activity. Pulp's widest usage are paper and paperboard production, 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 production 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 first volume focuses on the most important chemical pulping methods and includes six chapters. After a brief introduction, in chapter 2, *Raw Material for Pulp,* the raw material for pulp production including important aspects regarding wood chemical composition (organic and inorganic) its structure and morphology, cell wall components and functional elements is presented. A basic knowledge on the chemical composition and structure of wood is largely treated in this chapter. The five structural levels of observation are described: integral level (stem structure), macroscopic level (tissue structure), microscopic level (cell structure) ultrastructural level (cell wall structure) and biochemical level (biochemical composition of the cell wall). Valuable information regarding chemical comparison of various wood species, cellulose structure, hemicellulose composition and structure are also given. Structure of lignin, wood extractives and inorganic components are reviewed. The main differences between hardwood and softwood morphology and composition are underlined.

Wood processing as raw material for pulping is described in the chapter 3, *Wood Yard Operation*, dealing with basic aspects of wood storage, wood debarking and debarking equipment, wood chipping and chips screening together with important aspects of wood waste generation and reduction and pollution prevention opportunities. Raw material storage and measures that are required during storage in order to avoid wood losses and its microbiological deterioration are presented. The storage of logs and chips follows an inventory management procedure that reduces weathering and spoiling. An example of the material flow and processing steps at a pulp mill wood yard is also illustrated.

The goals of debarking and debarking methods are widely presented. The acceptable bark content in the chips depending on wood specie the pulping method is analyzed. Chipping and screening represents the largest paragraph of this chapter. The factors affecting chip dimensions and shapes are discussed. A special attention is given to the disc chippers. The cutting action of a knife in a disc chipper is analyzed regarding chips quality and energy consumption. The equipments involved in wood chipping and chips screening are presented. As the wood yard operations require suitable transportation and handling systems, the conveyors used for logs and for chips are illustrated. The problems of chip storage as: wood losses, temperature increasing, microbiological attack, moisture redistribution are underlined. A comparison between open-air chip storage and silo chip storage regarding their features is also presented. As the wood yard losses and waste reduction are important problems in a pulp mill, specific causes of waste generation are reviewed.

The fourth chapter of the first volume reveals the most important *Chemical Pulping Processes* including kraft pulping, sulfite and others such as

magnefite and alkaline sulfite. Kraft pulping is the dominating one in pulp production; therefore a large part of the chapter it is allocated (more than 250 pages). At the beginning, composition of typical white liquor and the terminology expressing the concentration of active chemicals are presented. Molar concentrations of hydroxide ions, hydrogen sulfide ions and carbonate ions in white liquors are determined. The evolution of the concentration of molecular and ionic species during the cook is also discussed. A special attention is given to mass transfer in kraft cooking due to the fact that the uniform distribution of the cooking chemicals within the chip void system is an important prerequisite for high-quality pulps production. Rapid and uniform impregnation can be achieved by chips steaming at atmospheric or superatmospheric pressure in order to remove interstitial air form the wood. The impregnation of white liquor by penetration is described as well as the molecular diffusion of the active chemicals into wood structure. The factors affecting white liquor impregnation are briefly presented. Effect of impregnation on the uniformity of delignification is correlated with the chips dimensions and wood species.

In pulping operations the lignin macromolecule must be degraded and dissolved to a major extent. Inter-lignin linkages are broken and the fragments dissolved in the pulping liquor. Understanding the lignin reactions in kraft pulping is of huge importance for obtaining a high-quality pulp. After the description of the general structure of lignin, the main lignin reaction types are reviewed. The residual lignin structure and chromophore formation are also presented. Reactions of carbohydrates such as peeling, stopping, alkaline hydrolysis, formation of hexenuronic acids are discussed. Some side reactions are presented as well. The course of delignification shows three stages: initial, bulk and residual delignification. Each stage is characterized by a specific rate of lignin removal, carbohydrates loss and by the level of alkali consumption. The selectivity of delignification strongly depends on the cooking stage. To improve the process selectivity means to develop kinetics models of kraft cooking. In this respect the models of delignification and carbohydrates degradation during kraft cooking are presented in the handbook. Effect of temperature, active chemicals concentration, wood chip dimensions and wood species on the pulping selectivity is largely discussed. Validation and application of some kinetics models are presented. Kraft cooking can be performed by different techniques. The proper choosing of the pulping method is very important from economically point of view and regarding pulp quality. Due to the fact that conventional kraft pulping in batch digesters is still in opeartion in many pulp mills, the factors affecting pulp yield and kappa number in standard batch cooking process are discussed. In order to increase the delignification degree without impairing pulp quality, the modified kraft cooking technique was developed recently. Principles of modified kraft cooking and parameters affecting this process are widely highlighted. The modern variants of batch cooking such as: Cold blow, Rapid Displacement Heating, Superbatch, Continuous batch cooking, Polisulphide cooking are compared.

Continuous cooking in hydraulic digesters represents today the most attractive cooking method. The recent enhancements of continuous cooking allow obtaining low kappa number pulps with good strength. The concepts of Modified Continuous Cooking, Extended Modified Cooking, Low-Solids Cooking are explained. Others modifications of continuous cooking as polysulphide and anthraquinone pulping and their influence on pulp quality is underlined.

Dissolving pulp represents a high-quality pulp grade and for its production a multistage kraft pulping is needed. Kraft pulping with hemicellulose prehydrolysis is necessary to obtain high alpha-cellulose content pulp. The handbook contains valuable information on this subject. Advanced liquor management techniques have been developed over the past decades for both batch and continuous cooking. This subject is emphasized in the handbook by the description of principles of displacement cooking. Batch and continuous cooking technologies and equipments are presented in more detail. The rules established for obtaining high-yield, high-strength pulp with good bleachability and low reject amounts are discussed. Sulfite pulping was the first method used for pulp producing. It was developed around acid calcium bisulfite process and remained the principal process for wood pulping until the beginning of the 1950s, when the need to recover the waste liquor and pulping chemicals slowly emerged, mainly for reasons of environmental protection. After that, many sulfite pulp mills were closed. However, different grades of sulfite pulp are still produced due to their specific properties. The strong position of sulfite technology in production of high-purity grades of dissolving pulp is the main reason that the handbook treats the sulfite chemical pulping as an important pulping method for pulp production.

Cooking chemicals and equilibria in sulfite cooking liquors are firstly discussed. The factors affecting the composition and stability of sulfite liquors are also underlined. The features of chips impregnation with sulfite liquors are explained for better understanding the importance of uniform distribution of cooking chemicals before temperature rising. Technological steps for satisfactory chip impregnation for acid sulfite cooking are presented.

Reactions in sulfite cooking are divided into lignin reactions, carbohydrates reactions and reactions of extractives. Lignin sulfonation is the main reaction which renders the lignin molecule sufficiently hydrophilic to be dissolved in the cooking liquor. The dissolution of lignosulphonates represents the main goal of sulfite delignification. This process depends on the liquor pH and temperature. A sulfitolytic or hydrolytic cleavage of the etheric bonds between lignin moieties occurs during the cook. The selectivity of the sulfite process and pulp proprerties highly depend on

the cooking regime. The handbook underlines the major importance of the acid catalyzed hydrolysis of glycosidic linkages of the carbohydrates. The depolymerization of cellulose and of dissolved polysaccharides leads to the formation of monosaccharides and their transformation products. Side reactions in sulfite pulping such as dehydration of carbohydrates to aromatic structures, formation of sulfur-containing carbohydrates, formation and role of tiosulfate, reactions of extractives are largely discussed. The basic technology of sulfite pulping, the stages of the process, the parametrers influencing the cook are underlined.

Alternative sulfite pulping concepts and the most successful developments are presentedin a subsection of the 4th chapter. The Magnefite process is largely treated due to its advantages regarding pulp characteristics and possibility to recover pulping chemicals. Alkaline sulfite pulping is reviewed for its lower costs and improving beatability and bleachability of pulp. An interesting variant, alkaline sulfite antraquinone pulping is disccused also. An important after cooking pulp processing operation - pulp washing – is discussed in chapter five. Obtaining pulp that is free of unwanted solubles is essential for further pulp processing. Pulp washing can be found in brownstock washing, in the bleach plant, and in oxygen delignificationas well. The chapter begins with the pulp washing theory, by an examination of the phenomena which influence the process. Drainage of filtrate plays a fundamental role in pulp washing. Handbook shows that good drainage is achievable by applying high differential pressure, limiting the mat thickness, keeping filtrate viscosity low, controlling the fines content in the pulp, and keeping the screen clean. Diffusion of dissolved substances and its sorption on the fibers surface are phenomena strongly influencing pulp washing.

Methods of pulp washing are discussed in a section of the handbook. The simplest method of washing is by repeated dilution and extraction. Pulp feed is mixed with washing liquor after which the filtrate is extracted from the pulp mat. The concept of displacement washing based on the idea of replacing the liquor in the pulp web with wash liquor is presented. Liquor removal by mechanical pressing (compressive dewatering) is analyzed too. A large section deals with the parameters influencing pulp washing that are classified according their importance. The pulp washing quality, washer capacity, and electrical energy consumption are influenced by a large number of parameters that are underlined in the handbook. In this regard, washing efficiency is treated in a separate section that contains the most important equations in pulp washing. Washing yield, displacement ratio and efficiency factor area taken into consideration in this regard. A wide variety of equipments is available for pulp washing, so that commonly used washer types and their features are examined in a subsection. Conventional drum washers drum displacers, belt washers, diffusion washers and roll presses are presented.

Pulp screening, cleaning and fractionation are presented in the sixth chapter of the first part. *Pulp Screening, Cleaning and Fractionation* chapter includes consequent presentation of fundamentals of these operations: theory and principles aspects, parameters and specific equipments. The terms of pulp screening, pulp cleaning and pulp fractionation are firstly discussed.

Screening operations can be located in both unbleached and bleached sections of the fiberline. Centrifugal cleaning is usually employed for bleached pulp. Fractionation leads to separation of cellulosic fibers according their dimensions. The principles of all these operations are presented in the handbook. Parameters influencing pulp screening are divided into screening parameters, operating parameters and furnish parameters. All these are fundamentally studied in an appropriate subsection of the handbook. Estimation of pulp screening and cleaning efficiency is important both for technologist and screen designer. The equations describing the efficiency indicators are discussed. Chapter six ends with applications of pulp cleaning and screening. An overview over the most common contaminants in the pulp coming from the digester is provided. The impurities are characterized according their origin, size, shape, rigidity, and density. The necessity to removal each fraction of impurity is justified. Systems for contaminant removal from both technological and economical point of view are given. are given. Fiber loss versus screen efficiency is exemplified for one-stage screening or multi-stage screening.

There is an abundance of different types of commercial screening equipments. Pressure screens and atmospheric screens are selected and briefly presented regarding their role and efficiency. Some types of centrifugal cleaners are also included at the end of the 6th chapter.

Handbook of Pulp edited by Herbert Sixta addresses to specialists working in the field of pulp and paper and represents a very valuable scientific and technological support. Based on very rich bibliographical references, the volume is obviously a very 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.

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