ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 30, E1, 2018, pp.68-72

Optimal Design of the Bleach Plant and Global Trends

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Abstract: *There is no such thing as a universal best design of a bleach plant, since there are several factors influencing the design. The aim of this paper is to summarize the factors influencing the design and their impact on the design of the bleach plant. Global trends like water consumption, effluent and energy efficiency will also be discussed.*

Key words: Oxygen Delignification; Bleach Plant; Water Consumption; Effluent; Global Trends

1. Introduction

There are several parameters to consider when designing the optimal bleach plant, some of the most important are: capacity, raw material, final pulp quality, environmental impact, operational costs, total investment cost and layout.

Pulp production, raw material and final pulp quality are governed by the raw material availability and targeted end customers. Location, national legislation or company policies will determine allowable effluents and fresh water consumption. Availability and local cost structure varies a lot around the globe, and hence configuration of the optimal bleach plant does too.

Discussion

The raw material and the final pulp quality sets the basis for the fiberline design. There are two distinct groups of raw material, namely softwood and hardwood, but there are several different species and clones within each group. On top of the vast number of species and clones there are also parameters like growth area, seasonal variations and relationship of round wood vs. sawmill chips which also will affect the operation of the fiberline. Hence the conditions for a well operating fiberline starts with a well-controlled wood yard to minimize unwanted variations.

When designing a fiberline one must also consider what the end-product should be used for to produce a pulp well suited for the purpose. The raw material sets the basis for the end-product quality, but it can also be tuned by fiberline design, beating and chemical additions. Typical quality parameters for bleached market kraft pulp are brightness, cleanliness, beatability, and strength properties, such as tensile strength. For dissolving pulp, properties like reactivity and solubility are important and parameters like viscosity, alpha-cellulose content and metal are being controlled.

Effluent volumes and quality is governed by geographic location and company policies. Depending on geographic location local legislations, local opinion and availability of natural resources can differ. EU released a new reference document on Best Available Techniques in 2015 (BREF), summarizing limits for emissions and effluent loads [1]. Over the last decades there has been enormous efforts in the industry to reduce especially water consumption and effluent loads, particularly absorbable organic halides (organically bound chlorides, AOX) and chemical oxygen demand (dissolved organic substance, COD). Financing institutes and banks are normally demanding that EU BATref or IFC Equator Principles are followed to give financing to investments.

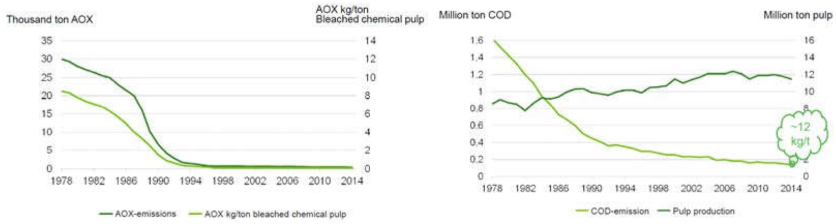

Figure 1. Water emission development from Swedish pulp and paper mills [2]

The reduction of COD- and AOX-emissions in figure 1 have been made possible by a combination of process measures and external treatment. Example of process measures are degree of closure and filtrate recirculation, introduction and increased efficiency of oxygen delignification, improved washing equipment, replacement of molecular chlorine with chlorine dioxide (ECF bleaching) and chlorine free bleaching chemicals like hydrogen peroxide and ozone. In the beginning of 1980´s biological effluent treatment was introduced, which resulted in an increased efficiency of external water treatment plants. Today many mills even have a tertiary chemical effluent treatment to achieve extremely low discharge levels. In the same time frame, i.e. end of 1970´s to current date, the effluent volume from the fiberline has reduced from around 70 m^3/ADt to 5-10 m^3/ADt. The ambition to reduce effluent volumes is global, there are modern mill references in most part of the world, see figure 2.

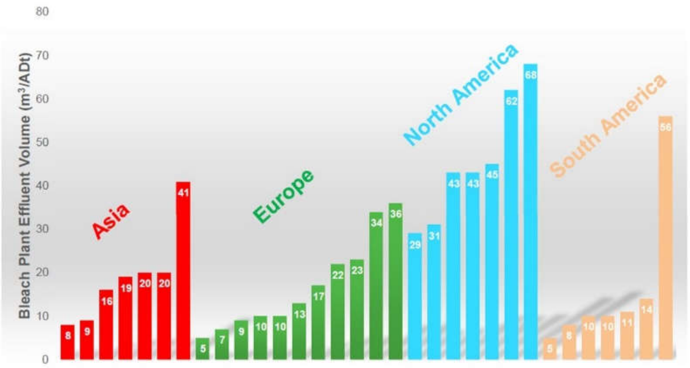

Figure 2. Bleach plant effluents from selected pulp mills globally

It is possible to reach effluent volumes of 8-9 m^3/ADt with a normally closed press based bleach plant, i.e. with both an alkaline and acidic effluent. To reach benchmark levels of 5 m^3/ADt, alkaline closure combined with wash press technology is necessary. Alkaline closure will increase the concentration of non-process elements (NPE´s). An increased amount of NPE´s will increase the risk of precipitation, so extra attention towards scaling should be taken in the design. Alkaline closure will also result in an increased amount of potassium and chloride in the black liquor, which must be considered in the recovery loop, by either ash leaching or ash crystallization. With as low effluent flows as 5 m^3/ADt from the fiberline it is possible to reach total mill effluents of as low as 7 m^3/ADt (excluding cooling water). Today there is even a benchmark pulp mill in China with 0 m^3/ADt mill effluent to the recipient, in this specific mill the mill effluent is used as cooling media in nearby process industries after treatment.

Fresh water consumption is a topic of increasing interest globally. Over the last years there has been mills that has been forced to reduce production or even stop the mill due to water shortage. Water addition in a fiberline consists of dilution factor in the alkaline and acidic filtrate loops of the bleach plant. In a press based bleach plant a wash liquor flow of 3 m^3/ADt is required to achieve a dilution factor of 1 m^3/ADt. To reduce the fresh water intake white water should be applied on the last washer prior to the pulp drier and secondary condensate could be applied to the other filtrate loop, see figure 3.

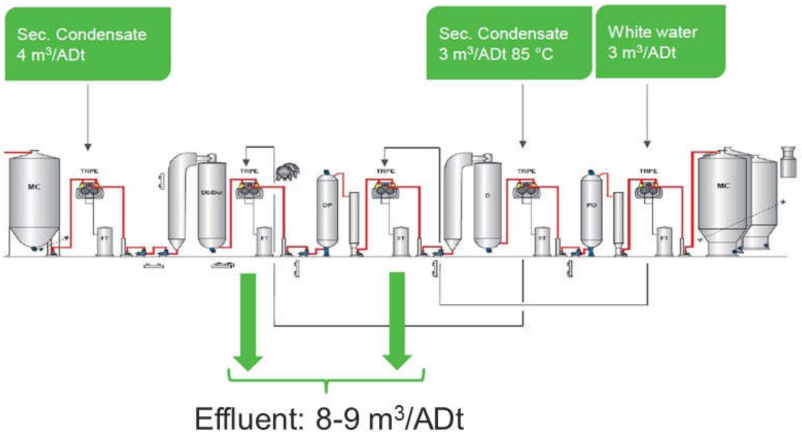

Figure 3. Optimization of condensate usage in the bleach plant, to minimize fresh water consumption

The biggest contributor to a pulp mills operational cost is the wood, ranging from approximately 40-70% of the total operating cost. The cost structure does however vary a lot globally depending mainly on availability, cost and taxation for power and transportation, see figure 4.

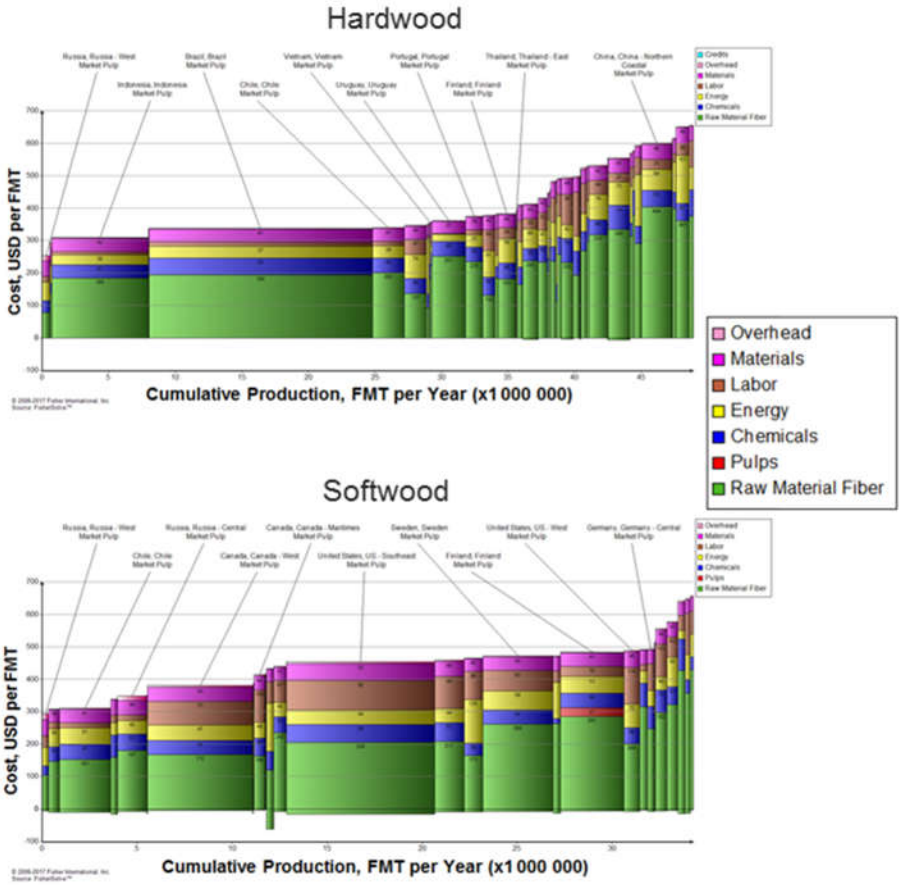

Figure 4. Global operational cost split for pulp producers [3]

The absolute values in figure 4 should be used with care, since there could be big variations within a country. The figure does however show that the cost for chemicals is fairly constant globally, but the cost for wood and energy varies.

Since the wood cost is the main operating cost for a pulp mill there has been a lot of focus on increasing the overall pulp yield over the years, one of the latest focus areas has been extended impregnation kraft cooking (EIC) [4]. By combining long impregnation time, low impregnation temperature and high L/W-ratios it has been possible to move the defibration point to higher kappa numbers and hence increasing the pulp yield. The laboratory results for EIC cooking have also been verified in mill scale tests, for instance in Fibria Aracruz mill, where the kappa number was increased from 16-18 to 20-23 without a relevant increase in reject [5]. During the Fibria mill trial the efficiency of the oxygen delignification increased by 5-7% [5] by adjustment of the operating conditions, but it was not enough to reach the same kappa number into the bleach plant, hence the chemical costs to reach the same final pulp brightness increased. With a modified oxygen delignification stage, it should however be possible to preserve the increased pulp yield obtained by EIC cooking and improve the efficiency to achieve the same kappa number into the bleach plant. Such modification could include additional retention time, increased partial pressure of oxygen, improved washing and split alkali charge.

Bleached kraft pulp

Bleached hardwood and softwood kraft market pulp are bulk products; hence there is a lot of focus on minimizing the investment cost per ton of pulp produced. The result is often pulp mills with high production, recent eucalyptus and acacia mills have been designed for an annual production of 1.5 to 2.3 million tones whereas new softwood mill investments have been designed for 0.7 to 1 million tones per year. Bleached softwood pulp is often used as reinforcement in high quality tissue and low basis weight coated paper, hence the demand for pulp quality is normally higher compared to hardwood pulp. The wood costs for hardwood is lower than for softwood, but it still accounts for the biggest part of the production cost, hence a lot of focus has been on increasing the wood utilization. This has been achieved by optimizing the forest productivity and applying improved cooking technologies.

The focus for the fiberline is to preserve the pulp yield and increase the brightness at minimum cost. The most economical way to achieve this varies globally due to the variations in cost structure illustrated in figure 4, however the most common hardwood fiberlines currently consists of a two-stage oxygen delignification followed by either a three-stage D_{ht}(EP)D or a four stage D_{ht}(EP)DP bleach plant. A low capital investment alternative, could be a two-stage bleach plant D_{ht}(PO) for easily bleached eucalyptus. To optimize the water consumption, energy consumption and effluent amount wash press technology is applied.

A first combined hot acid stage and chlorine dioxide stage, D_{ht}, has become dominant for hardwood pulp, due to the amount of hexenuronic acid present in the pulp, and has proved to be superior to D0 and (AD) for hardwood pulps [6,7]. Local conditions or preferences will however impact the final concept; alternative solution could include substituting one chlorine dioxide stage with ozone. Ozone plays an important role when effluent color and/or AOX demands are higher than BAT.

A standard softwood fiberline has many similarities to the typical hardwood fiberline illustrated in figure 5. Instead of an initial D_{ht}-stage a D0-stage is applied, the D0-stage operates at lower temperature and shorter retention time, i.e. a pure chlorine dioxide bleaching stage.

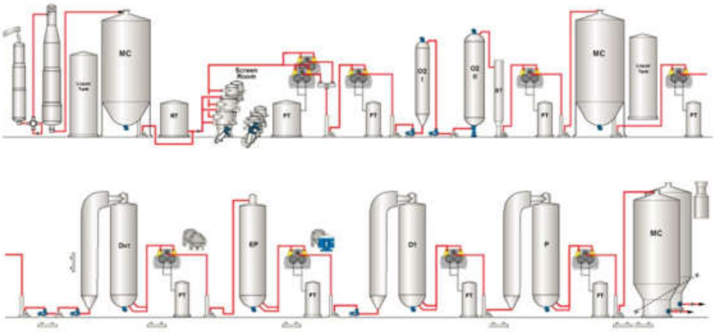

Figure 5. Typical modern hardwood fiberline

Dissolving pulp

If bleached hardwood and softwood market pulps are bulk products it´s quite the opposite for dissolving pulp. Dissolving pulp can be compared to a chemical product with vary narrow product specifications. The main end-usage for dissolving pulp is viscose followed by acetate and ethers. A typical fiberline for dissolving production for viscose industry is shown in Figure 6.

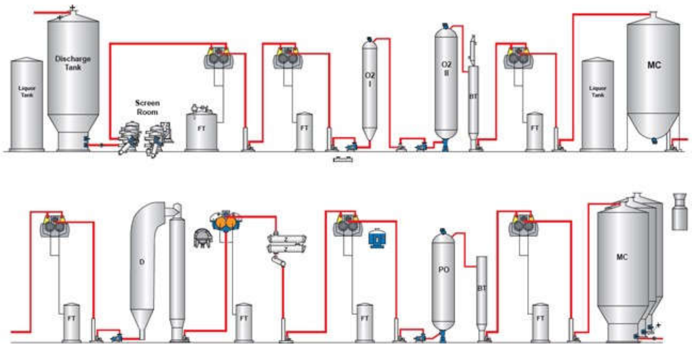

Figure 6. Typical modern dissolving fiberline for viscose production

One difference compared to a fiberline for standard bleached kraft grade, is the need for narrow viscosity control, which for instance be achieved with an ozone stage as in figure 6. For high-alpha cellulose grades, for instance acetate pulp, a cold caustic extraction stage might be necessary.

Conclusions

There is no such thing as a universal best design of a bleach plant, since there are several factors influencing the design. The major contributing factor to the design are raw material, end-product and environmental impact.

Sustainability is high up on the global agenda, therefore a lot of effort is put on increasing pulp yield, reducing water consumption, increasing energy efficiency and reducing emissions both to water and air. Pulp mills are therefore constantly increasing cooking kappa targets, integrating mill islands and reducing effluents by filtrate circulations and gas collection. With an optimized integration between the fiberline, pulp drier and evaporation it is possible to reach zero fresh water intake to the fiberline. If at the same time alkaline filtrate circulation is adopted, an effluent flow of 5 m^3/ADt from the fiberline is possible in a press based fiberline, resulting in a total mill effluent of as low as 7 m^3/ADt (excluding cooling water). The mill effluent could, after treatment, be utilized as cooling water in nearby process industries and thus the zero-water effluent mill is no longer a vision but in fact a reality.

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