Impact Of Water Loop Closure In Deinking/Recycling Mills

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ABSTRACT

Papermakers are under increasing pressure to reduce specific water consumption. While reduction in fresh water is a cherished goal, its attainment is linked with consequences on the process. Without a specific work to optimize the water circuit arrangement, the reduction in the fresh water use can lead to many perturbations on the runability of the paper machine. Usually, circuit closure is achieved though recycling of the back water after particle separation. As these waters are highly concentrated in contaminants like dissolved & colloidal solids, salts and surface active species which buildup in the process loops, various disturbances in the deinking process are encountered, viz., reduced efficiency of wet-end aids, reduced felt efficiency, deposits, odors (through microbial development) and corrosion. A higher water temperature also has an impact on the wet-end chemistry and reduces the efficiency of vacuum pumps.

While conceptualization on reducing fresh water consumption and ultimate closing up of water systems; water chemistry, biology and the probable technologies are to be thoroughly studied. The fresh water consumption in a specific mill is strongly dependent on raw material used, paper grade produced, water circuits, machine configuration and speed, treatment facility of waste water. The present paper presents an overview of the different problems/ limitations and case studies associated with water loop closure and possible approaches to ultimately target zero effluent in the deinked paper industry.

Introduction

The pulp and paper industry is one of the highest water consumers among major industries. The reason for high water consumption is apparently simple: more water a mill uses, cleaner will be the pulp and the processes. The water removes unwelcome contaminants that may cause dirt in the pulp, difficulties in bleaching, and incrustations and plugging in the process. Colloids, mineral ions, chromophoric groups, wood extractives, organic radicals, slime, stickies, and a lot more, may be eliminated from the process through the water. Enormous water consumption may be good to the process, but bad to the environment. In view of declining availability of fresh water supplies, efficient water management is crucial for every industrial sector including pulp and paper; utilization of fresh water should be oriented towards carrying the process operation in a sustainable manner. Water consumption in the recycled fibre (RCF) based mills is given in Table 1.

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Table 1: Water consumption in RCF based mills

Section	Water Consumption m^3/t paper
Pulp mill	5-20
Stock preparation & paper machine	15-40
Miscellaneous	5-15
Total	25-75

Circuit closure in deinking/recycling based mills needs to be considered in more broader context of the paper mill operation. Adjustment of fresh water consumption has an impact on the whole mill water circuits.

Anticipated consequences of circuit closure on deinking process efficiency

Build-up of dissolved and colloidal substances (DCS)

DCS build-up in the circuit can modify physico-chemical condition and increase flotation losses (Pirttinen and Stenius 1998, Carré et al. 2001, Prud'homme and Khan 1996). Build-up of anionic colloids will also reduce efficiency of charged polymeric additives, thus impair flocculation in DAF units, and retention/drainage in the wet-end.

DCS analysis from deinked pulp (DIP) and thermo-mechanical pulp (TMP) blends has shown that the anionic trash mainly originates from the TMP fraction (Garver et al. 1997). Mixing of the two pulp streams can be the source of problems. Circuit closure is generally anticipated to affect final paper properties. It is believed that DCS retained in the sheet impairs inter-fibre bonding. It has been showed that it is the amount of colloidal substances in the process water, rather than the amount of dissolved substances that is critical for sheet strength (H. L. Lee et al. 2006). This was true for old corrugated containers (OCC), newsprint and fine paper grades. It has been claimed that the tensile strength was most strongly affected by the colloidal solids, while the burst index, bulk and porosity were most strongly affected by the dissolved solids in the white water (Francis and Ouchi 2001).

Build-up of conductivity and calcium
When closing the circuits, ionic species will build-up in the process loops. The conductivity is anticipated to reach similar levels, whether sludge press filtrate or bio effluent is recycled. The consequences on the deinking process, due to the overall increase of ionic strength, are thought to be detrimental in general.
The sources of calcium on the deinking process are clearly not fully elucidated, and closely depend on recovered paper grades and deinking chemistry. In all cases however, calcium build-up in the circuit should be avoided, in order to limit scaling phenomena. Increasing calcium concentration, pH, alkalinity or temperature enhances the scaling tendency of process waters.
It is often said that circuit closure causes enhanced corrosion. However, high conductivity does not necessarily lead to corrosion. It is the ratio of sulphate, chloride and thiosulfate concentration which is critical for most alloys.

Microbial activity
Build-up of organic matter in the process loops (starch released from recovered papers, etc.) increases nutrients for bacteria. Thus bacterial growth and especially slime deposition may become problematic in some cases. Severe closure generally shifts the bacteria population to anaerobic. Due to increased temperature in the process, oxygen is depleted from the water phase. This leads to production of volatile fatty acids (VFA), drop in pH and cause odour problems; butyric and propionic acids are most critical (Gudlauski 1996, Göttsching 1997). The effect of pH on deinking efficiency is dependent on the type of raw material; in general, alkaline pH favors ink detachment.

Build-up of surfactant
Surface active substances are also released from the raw material. Wood-containing coated papers are a major source of surfactant. Repulping of rotogravure printed papers causes a major release of synthetic surfactant (Zeno 2004).
Surface active substances stabilize smaller air bubbles, which rise more slowly to the top of the flotation cell (Beneventi et al. 2006). This increases gas hold-up in flotation cells, which leads to better ink removal but higher losses (Huber et al. 2011). Surfactant build-up has been shown to be detrimental to flotation, reason being the increased foaming (Haynes and Marcoux 1997).

Minimizing water usage

Cooling water network
Recycling the hot water in the fresh water network to the paper machine presents real advantages. There is no disadvantage because the only modification in the physico-chemical quality of the water leaving the cooling circuit is the change of temperature. The cooling water system can be partially closed with the installation of cooling tower.

Preparation and dilution of chemicals
The water used for the preparation of chemicals should be free from ionic substances because pollutant introduced in this step will greatly alter the quality and efficiency of chemicals. Some chemicals need dilution just before sending them to pulp flow. The contact between the water of dilution and the chemicals before their contact with the pulp is very short. It is possible to use clarified water instead of fresh water for dilution.

Paper machine showers
Clear or super-clear white water from the save-all is increasingly used in wet end wire showers. Wire shower system requires adequate showers, nozzles and shower cleaning equipment with an internal brush or other purging equipment. To avoid plugging of the nozzle due to dysfunction of the save-all, water distribution to such showers should go through a protective in-fine strainer, preferably of the slotted type and equipped with an automatic purge. The opening size of this filter should not exceed 1/6th of the spray nozzle diameter. To avoid plugging the nozzle, the particle size is more important than the consistency. The use of clarified water to feed felt showers needs a stronger filtration step.

Sealing waters
Sealing water used for circulating pumps can represent a high use of fresh water. Vacuum pumps also need large quantities of sealing water. A recycling loop is recommended for part of the vacuum pump sealing water with integrated cooling and solids removal. Paper machine vacuum pump that recycle used sealing water must have strainers and, in the case of a high recycling rate, cooling system in recycling line is required to maintain a high vacuum.

Optimum water circuit layout
Separation of water loops together with counter-current flows
This measure concerns the recovered paper based mills. Recovered fibres are the main polluting source of soluble organic material. The principle of separation of water loops means, that the pulp department, the bleaching department and the paper mill department each have its own water circuit. The excess white water from paper machine loop goes backwards to the pulp mill where water quality is less demanding; water flow is counter current to the product flow. The separation of the water loops is carried out with thickeners. The extra thickener leads to an improved separation of the "dirty" stock preparation water and significant reduction of organic substances that enter the machine loop. The excess water from the whole system comes from the first loop i.e. the pulping department. Fresh water is mainly used in the paper machine loop. This arrangement can reduce the organic load by a factor of between 2 to 4.

Broke system management
Another important factor in closing the white water system regarding the wet-end stability is to separate the broke and white water system. Mixing broke with the white water system causes significant flow variations in the white water system. Desired broke system involves pumping from the couch pit and the dry-end pulper to a common storage tank. From there, it passes through a cleaning device and a deflaker to the blend chest with a controlled flow and a controlled consistency. In line consistency control of the stock from the broke chest to blend chest is essential.

Water clarification and recycling of process water
The main principle of an optimal water arrangement is to re-use process water in the system, counter current to the fibre flow. The white water from the paper machine is used for stock dilution before the fan pump (short circulation).

The overflow is clarified in saveall. One of the most important components of the paper machine white water system is the saveall which separate liquids from solids. The saveall clarified water can then be used in mill applications for adjusting stock consistency and substitution of fresh water application such as paper machine showers. Clarification is achieved by sedimentation, flotation or filtration.

Flotation save-alls are effective in removing suspended and colloidal material but need the help of coagulant/flocculant agents. At optimum conditions, flotation save-alls have a good TSS removal efficiency.

In a disk filter, liquid is forced through the filter layer by applying a vacuum. The build-up of the fibres on the filter wire serves as the main filtration medium. The white water filtrate is typically collected as two separate, cloudy and clear fractions. Thus, clear filtrate can be used in paper machines. The cloudy filtrate is readily re-used in machine broke pulping and stock dilution.

Adequate storage capacity

The most important item keeping the accidental discharges to a minimum is the correct sizing of the process water and broke chests. The white water storage capacity must match this broke storage so that no fresh water is required during sheet breaks or when the broke is returned to the machine. But the storage capacity of pulp, broke and process water should be optimized so that it is not too large, because of microbial activity and not too small to avoid the need to add fresh water for level control.

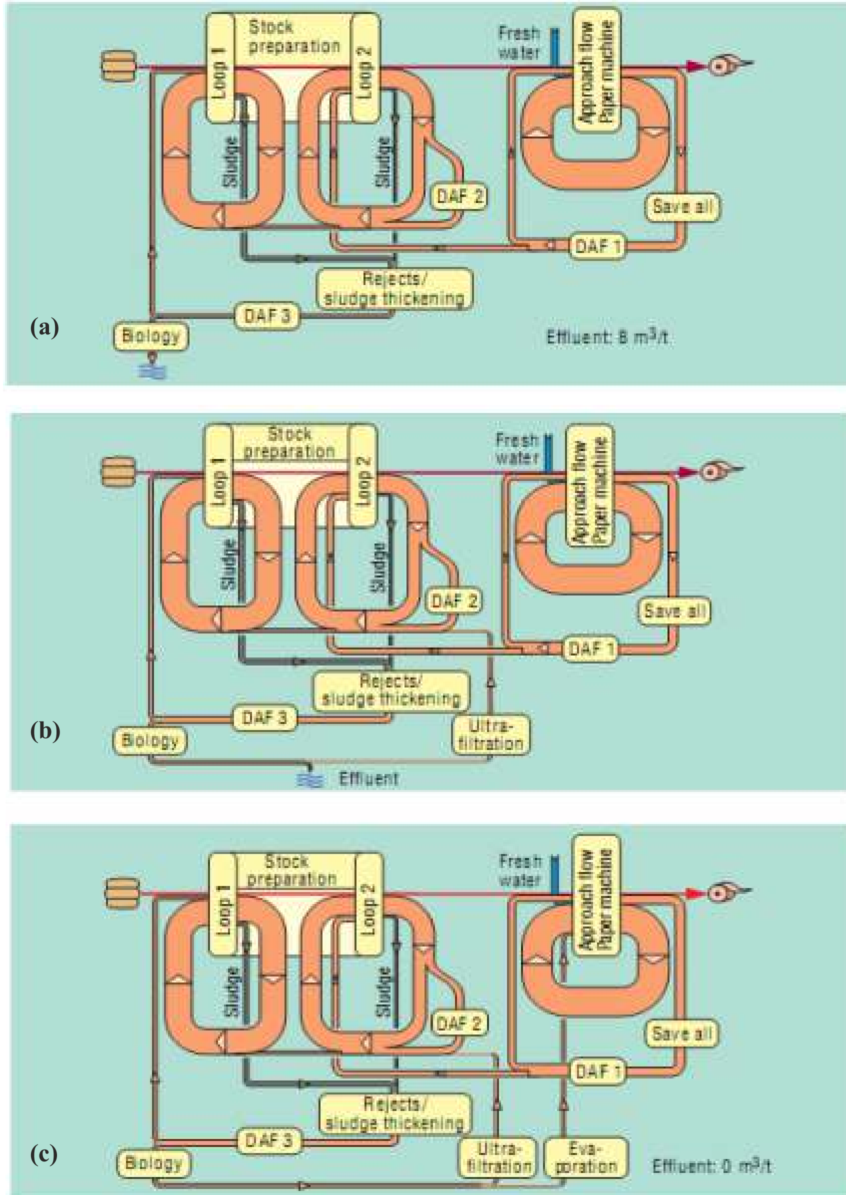

Fig.1 (a) Water management for limited effluent, (b) Water management for a greater degree of water loop water closure, (c) Water management for zero effluent.

Strategies for circuit closure

Assuming that the circuits are arranged according to the optimal water management rules, there are several strategies to close the water circuits. There are two options to recycle the sludge pressing effluent. Firstly, increasing fraction of the effluent can be recycled to the stock preparation (usually to 1st loop DAF).

Fig. 1 illustrates the water loop in a typical newsprint mill. The process components are block wise combined into water loops. Water routing consistently follows the counter current principle. Fresh water is added only at the paper machine. Following filtration, surplus white water is cleaned in the fibre recovery stage and used for dilution after the storage tower or in Loop 2 in stock preparation. Loop 2 supplements Loop 1. The filtrates from sludge dewatering and rejects thickening can be cleaned via a separate micro flotation, if a partial flow is routed back into Loop 1. The other section represents the actual system discharge. The effluent is cleaned biologically before being discharged from the mill. Specific effluent volumes of approximately 8 m^3/t are achievable without compromising the process technology or product quality.

If, however, the flow from the biology stage is directly fed back even after efficient mechanical/chemical post cleaningthen microorganisms or their metabolism will unquestionably be carried into the process water. Fig. 1b schematically illustrates that a partial flow from the biology stage is cleaned through ultra filtration, before it is routed into Loop 2.

Detailed balancing of process water shows that loop closure up to approximately 4 m^3/t can be achieved. This remaining effluent volume is basically essential to flush out the salt load brought in with the recycled paper and additives. With optimum process design (no aluminium sulfate, no dithionite) a reduction down to 2m^3/t is feasible when the high brightness of the DIP is not desired. The transition from these contemplations to the scenario illustrated in Fig. 1c is smooth. If a fully closed loop is required, a specific water volume of approximately 4m^3/t must be evaporated.

6. Case studies

The most emblematic case of total circuit closure is the Kappa Zülpich mill, Germany. To reach complete closure, an integrated biological process water treatment plant was installed (UASB reactor + double line activated sludge plant as aerobic stage + sand filter). This clarified bio water is recycled back to the stock preparation. Scaling problems are handled by enriching the effluent in CO_2 from the exhaust of the biogas flare (Habets et al. 1997). Before integrating bio-treatment, the COD in white water was 34 g/L, and decreased to 8 g/L afterwards (Göttsching 1997).

Julius Schulte Söhne Mill, another mill in Germany also reached the zero effluent targets. They implemented an IC reactor (internal circulation) as anaerobic stage + aeration reactor + sand filter. Lime milk is added to help decarbonatation, and softening rate of 50 to 90% are achieved. If water hardness can be closely controlled, the conductivity in the mill circuits drastically increases after closure, mainly due to chloride. The bio water is recycled to the paper machine loop in substitution for fresh water, for felt and wire conditioning (Bulow et al., 2003). In this case, VFAs levels were not reduced. COD in paper machine white water slightly decreased after closure, as a result of the anaerobic + aerobic treatment (Habets et al., 2000).

Spanish Paper Mill, Papelera de la Alqueria (2000) produces 210 t/day of fluting and test liner. In completely closed water system in the mill (Fig. 7) recovered fibers are reused in the fabrication and the clarified water is used for various purposes in the mill. As shown in the flow diagram (Fig. 7), the total mill effluent is collected in tank [2] and pumped to the first flotation cell [4]. Part of the clarified water from flotation cell is pumped from tank [5] to the second flotation cell. Floated solids are recycled into the production of the clarified water and reused for suitable applications. Part of flotation cell [6] clarified water is pumped from tank [7] to the third flotation cell [9]. Floated solids are returned to the paper machine and screened, clarified water is used where clean water is required. Fresh water is provided to compensate for evaporation and other losses.

Conclusion

Closing up of a water system involves a custom-made approach for each paper mill, due to the many individualities of the mill installation. The benefits of a closed deinking paper mill are considerable with respect to increased process efficiency and zero waste-water discharge. In most cases, the closed system pays for itself without even considering the pollution control benefits. In addition to heat savings, savings in recovered fiber, clay, chemicals, and of course water are all significant.

Before reducing fresh water consumption, intricacies associated with the closing-up of water systems need to be carefully studied. The minimum acceptable fresh water consumption is strongly mill-dependent (raw material, paper grade, initial circuits). The broad methodology described in the paper provides a global view of the water circuit arrangement and allows to re-organize the system, in order to improve water quality for recycling.

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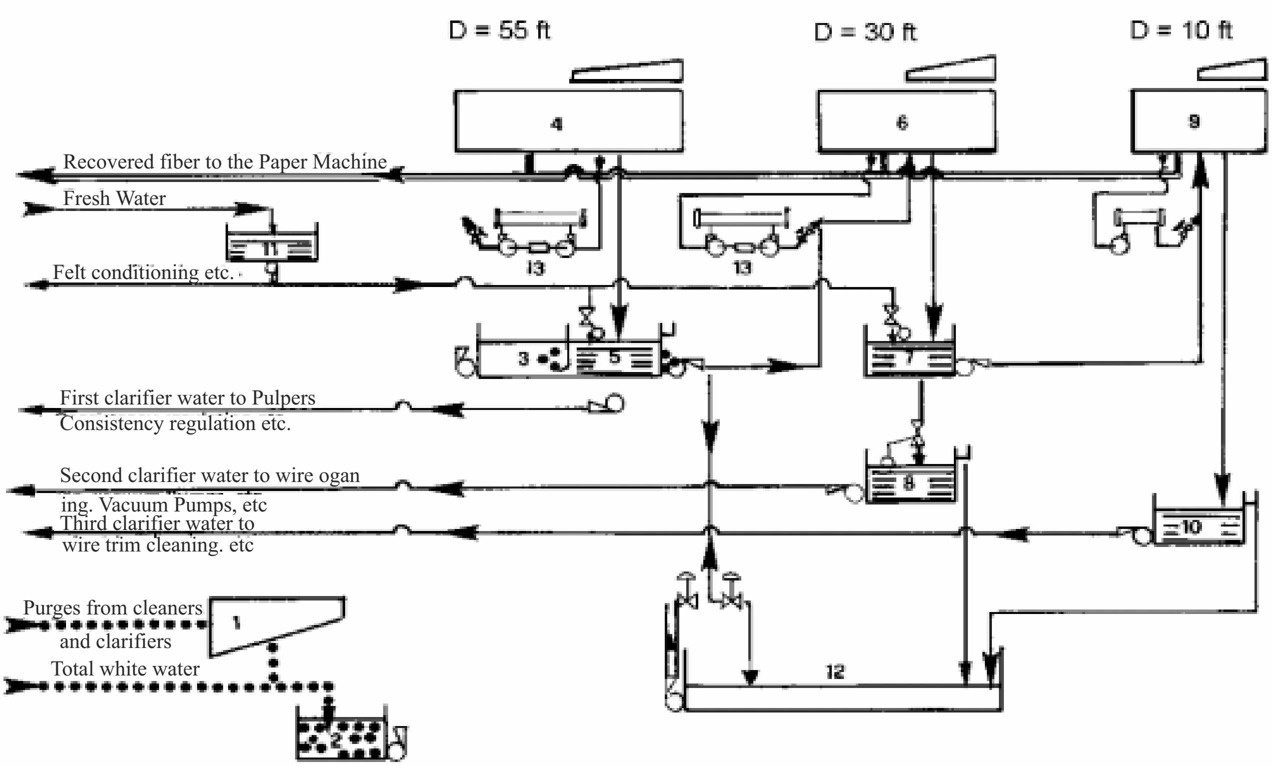

Fig.7. Flow diagram of the closed water system in Spanish paper mill.

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