Introduction

The current trend in the papermaking industry is toward closed-loop water circuits resulting in greatly reduced or eliminated effluent discharge to the environment. There are several difficulties encountered in any closed-loop plan implementation including identifying the best technology for wastewater treatment, waste sludge disposal, and possible cycling up of undesirable contaminants in the water loop. With recycle mills, these difficulties are even greater. The recycling of recovered paper introduces other contaminants that come from paper additives used during the original papermaking and foreign matter or debris brought in with the waste paper. High levels of contaminants in the water loop can give rise to severe deterioration in recycled paper quality, as well as to productivity problems caused by surface contamination, odor, formation and runnability.

In spite of these difficulties during design and start up of a closed loop system, there are many benefits that can result once successful. Some benefits include: reduction in the cost of importing fresh water from local tributaries or wells, the elimination of effluent discharged to local waterways or the POTW, reduced regulatory liabilities, and reduction in energy consumption since treated water is already partially heated.

Good water management in the paper industry allows papermakers to reduce the water consumption without affecting the quality of the final product or the production process. The systems used for water closure depend basically on the mill configuration, The best available technology to move towards zero liquid effluents is a correct balance between the internal water recirculation and the external treatment of the final effluent. Technological advances in membrane filtration systems have created an opportunity for pulp and paper mills to treat effluent streams for successful reuse or to meet stricter environmental constraints. The new “Vibratory Shear Enhanced Process” or VSEP, developed by New Logic Research makes it possible to filter effluent streams without the fouling problems exhibited by conventional membrane systems. The VSEP membrane system will significantly reduce BOD, COD, TDS, TSS and color bodies from effluent streams discharged from pulp and paper mills, thus minimizing treatment cost.

Membrane Filtration

The advantage of the pure ionic separation with polymeric membranes has always held the interest of those wishing to treat paper mill effluent. In the past, the limitations of conventional membrane systems have prevented widespread use because of limitations when it comes to suspended solids content. Colloidal fouling obstructs the pores of the membrane and greatly reduces the throughput and increases the frequency and amount of cleaning required.

To combat this problem, elaborate pretreatment is used to prevent scale formation inside the membrane system. Even with all of these improvements, the limitations of conventional membranes have not allowed their widespread use in closed-loop paper mills. Some of the disadvantages of conventional membranes in treating plant effluent include:

Long membrane cleaning cycles
Fouling from colloidal mineral scale
Elaborate pretreatment
Large foot print area
Complex treatment system design
High energy usage
Chemical handling requirements

VSEP vs Conventional Membranes

A new membrane system know as VSEP, (vibratory shear enhanced process) employs torsional vibration of the membrane surface, which creates very high shearing energy at the surface and near the pores. The result is that colloidal fouling and polarization of the membrane due to concentration of rejected materials are greatly reduced. Since colloidal scale fouling is avoided because of the vibration, the use of pretreatment to prevent scale formation is not required. In addition, the throughput rates of VSEP are 5-15 times higher in terms of GFD (gallons per square foot per day). The sinusoidal shear waves propagating from the membrane surface act to hold suspended particles above the membrane surface allowing free transport of the liquid media through the membrane. This accounts for the increased performance of VSEP membrane filtration when compared to conventional crossflow membrane filtration.

The VSEP membrane system is a vertical plate and frame type of construction where membrane leafs are stacked by the hundreds on top of each other. The result of this is that the horizontal footprint of the unit is very small. As much as 2000 square feet (185 m2) of membrane is contained in one VSEP module with a footprint of only 4' x 4'. This combined with the very low energy consumption, makes VSEP a very attractive alternative especially for older plant installations where space is a premium. Recent studies conducted using VSEP for treatment of paper mill effluent have shown the benefits of vibration. Some of the advantages of VSEP for high solids applications include:

1] Higher throughput per square foot of membrane when compared to other membrane systems

2] No pretreatment chemicals are required to prevent scale formation

3] Extremely energy efficient (.27 kW per 1000 gal of filtrate)

4] Small footprint and simple process design

5] Wide range of membranes possible for use from Microfiltration through Reverse Osmosis

VSEP has made it possible to dewater or separate high solids applications previously not possible with conventional membranes. This has created an opportunity in the paper making industry for a technologically advanced separation device that can efficiently process pulp waste products. In this particular case, the new VSEP technology was used to further concentrate reject solids to an even higher level than the already installed conventional membrane system. The ability to reach high solids in this case was only possible because of Vibrational Filtration utilizing polymeric membranes.

Nanofiltration

Recycled water used in a paper mill should be at the very least softened with scale forming anions and cations removed. In addition, oil and other organics must be removed. Nanofiltration membranes are capable of removing virtually all oil and are very effective at rejecting divalent and multivalent ions. Most membranes are negatively charged. Anions with two or more exposed electrons are easily repelled by the nano-filtration membrane structure. Nanofiltration and reverse osmosis membranes both act by diffusing liquids through their molecular structure. Ultrafiltration membranes have actual pores or small openings in the media and rejection is based on size classification. NF and RO membranes have a more sophisticated method of rejecting substances.

It can be very difficult for a divalent anion with a minus two charge to diffuse its way through the negatively charge membrane matrix structure. Monovalent anions are able to pass more easily because of the lower electrical potential and the fact that they are generally smaller.

As the divalent anions are held back, positively charged cations are needed to maintain electrical balance. This is known as Donnan Equilibrium. Because of this, divalent metal ions remain on the reject side of the membrane in proportion to the rejected anionic species. Ions such as Calcium, Barium, Strontium, Magnesium, Copper, Zinc, and Iron are held back quite effectively by nano-filtration membranes. Holding back metals, sulfates, carbonates, and phosphates produces "softened" permeate, which is water low in scale forming species. Because the filtration occurs by diffusion, nano-filtration membranes are able to reject very small non-charged particles. NF membranes have a specific size rejection capability known as "molecular weight cut off" (mwco). The value of this is measured as 150-200 Daltons. This means that even very small organic molecules can be rejected. NF membranes have good rejection characteristics of benzene, tolulene, dichloroehtane, and other volatile organic carbons.
Re-use of this water is also beneficial since it is already warm and energy savings can result. Modern Nanofiltration membranes are capable of operating at temperatures of 60º-90ºC. Clean up and recirculation of this water can result in very significant energy cost savings when compared to heating fresh untreated water.

Case Study Installation

A VSEP membrane filtration system was installed at a Southeastern recycle paper mill producing linerboard and medium from OCC and MOW furnish. The company produces 500 tons per day of recycled high performance liners and medium for the production of corrugated boxes. Over 200,000 tons per year of old corrugated boxes; newspapers and magazines are diverted from landfills to be recycled into World Class Paper. The mill has many unique features including zero process water discharge. The company's one of a kind water cleaning system removes impurities from the mill's process water and the cleaned water is recycled into the papermaking process. The mill currently discharges only approximately 25,000 tons of waste materials a year to land fill. Approximately 18,000 tons of this land filled waste material will be converted into another product to be sold outside the paper industry in the future.

Process Description:

Like all recycle mills, the contaminant load varies depending on the furnish quality supplied. The mills' stock prep system is very efficient in removing contaminates allowing them to produce a high quality liner sheet. However, this mill is quite unique in that it has no effluent discharge stream. Therefore as a closed mill, the success of the mills papermaking operation is closely tied to the operation of their wastewater treatment plant to provide high quality water for reuse in the paper mill. At the same time, the contaminants must be reduced to a level where they can be disposed as a solid waste.

The wastewater treatment system at this mill utilizes a DAF clarifier to remove suspended solids and fines from the effluent stream, quite typical of most recycle mills. Part of the overflow from the clarifier is directly returned to the mill for reuse, with the balance having to be treated to produce recovered water that would not impact the papermaking process. Furnish used at the mill contains a significant amount of starch (50-60 lbs per ton) from OCC along with fillers and coating from MOW. The wastewater treatment process has to provide for removal of fines and starch along with a significant amount of COD to avoid any problems relating to formation and retention issues on the paper machine. DAF clarifiers are quite effective in treating effluent from a recycle paper mill to reduce solids to a level of about 75-100 ppm. Originally, a two stage conventional tubular ultra-filtration (UF) membrane system was installed to treat a portion of the overflow from the clarifier, removing suspend and colloidal solids. Eventually, it was recognized that the reject volume from the UF system needed to be reduced and an improvement in water quality from the membrane system would be beneficial. The VSEP system provided the solution.

After significant evaluation and testing by the mill, a VSEP nano-filtration (NF) membrane system was purchased and installed as tertiary stage treatment. The use of nano-filtration membrane provides for removal of significant amounts of dissolved solids from the feed stream, thereby producing excellent permeate quality for reuse. Even though the feed was very concentrated coming from the 2nd stage UF system along with some 1st stage reject, the VSEP is uniquely capable to handle this reject stream. COD levels in the recovered water returned to the mill were reduced with the VSEP permeate having a higher quality than the UF system permeate providing the balance required for COD levels in the overall water balance. This customer had an existing UF membrane system that was already returning UF permeate back in the process. During initial testing, VSEP UF was being considered. After additional testing, it was decided to use nanofiltration instead of ultrafiltration in order to produce a cleaner recycled water that would result in overall lower TDS levels in their water loop. The image to the left shows some of the various permeate qualities possible with UF and NF polymeric membranes. Reduction in overall TDS and scale forming molecules will result in lower maintenance costs and better paper product quality. If the customer replaced his UF system with NF, there would be added savings.

Performance Results

VSEP's Nanofiltration membrane module is capable of treating recycle mill effluent and providing a filtrate, which is free from suspended solids and low in COD and multi-valent sparingly soluble scaling salts. For concentrated effluent, VSEP modules containing about 1300 ft2 of filtration media are modular and can be run in parallel as needed to meet any process flow requirements. Each 84" VSEP module produces up to18 gpm of clean water in this case after two stages of Ultrafiltration. System throughput is a function of the extent to which the feed is concentrated and will vary from site to site. The VSEP module is also uniquely capable of high recovery of filtrate due to its scaling resistance. In this case, 72% recovery was achieved resulting in concentrated reject with total solids of over 20%. The system was initially designed to operate at about 350 psi, but due to overdesign of the system, it is only necessary to operate it at 150 psi to yield the same throughput.

Module Design

The industrial VSEP unit contains hundreds of sheets of membranes, which are arrayed as parallel disks separated by gaskets. The disk stack is contained within a fiberglass reinforced plastic cylinder (FRP). This entire assembly is vibrated in torsional oscillation, similar in principle to the agitation of a washing machine. VSEP can produce extremely high shear energy at the surface of the membrane. The membrane module is attached to a spring assembly and moves at an amplitude of 7/8" peak-to-peak displacement. The membrane module oscillates at between 50 and 55 Hz.

The fluid is gently pumped through the module while a highly focused shear zone at the surface of the membrane is created by the resonating oscillation. Rejected solids at the membrane surface are repelled by the shear waves and are washed away becoming more and more concentrated until the reject exits the module. An AC motor controlled by a variable frequency speed controller provides the resonant excitation that produces the vibration. The motor spins an eccentric weight coupled to the heavy seismic mass. Since the eccentricity of the weight (i.e., its center of mass lies heavily on one geometric side) induces a wobble, the Seismic Mass begins to move as the motor speed increases. This energy is transmitted up the torsion spring inducing the same wobble in the filter pack, however 180˚ out of phase. As the motor speed approaches the resonance frequency, the amplitude of the moving filter pack reaches a maximum. The resonant frequency vibration employed by VSEP is extremely energy efficient.

System Automation

The VSEP membrane filtration system has been designed specifically for the chemical processing user. The systems are completely automated, compact, and reliable. With very few moving parts, maintenance is simplified. Each VSEP system built is custom designed for a particular application with special materials of construction including exotic alloys and thermoplastics to fit the job. The VSEP is a complete integrated Plug and Play process requiring only process in and process out connections during installation. The system is controlled using a sophisticated Allen Bradley Industrial Computer that monitors data and implements the program functions in a seamless and automatic process. The VSEP controls are compatible with plant Distributed Control Systems (DCS) and can be operated as stand-alone devices or as a component of a much larger process

Operation of the VSEP is automatic through a PLC system tied in with the mills DCS system for data storage. The control system provides for automatic membrane cleaning in must less time and with less chemical usage than the primary and secondary conventional UF membrane system. The system has proven to be successful in meeting all process objectives and has performed well to provide high quality water for the paper mill.

Company Profile

New Logic is a privately held corporation located in Emeryville, CA approximately 10 miles from San Francisco. New Logic markets, engineers, and manufactures a membrane dewatering and filtration systems used for chemical processing, waste streams, pulp & paper processing, mining operations, and drinking water applications. The VSEP technology was invented by Dr. Brad Culkin in 1985. Dr. Culkin holds a Ph. D. in Chemical Engineering and was formerly a senior scientist with Dorr-Oliver Corporation.

About the Author: Greg Johnson, Chief Operating Officer, has been with New Logic Research since 1992 and has a Chemical Engineering background. He is responsible for engineering and design of the patented VSEP Vibratory Membrane System.

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