New Subsystems to Meet Current and Future Demands in Recycled Fiber Applications

Joachim Kleuser and Tom H. Egenes

ABSTRACT:-- For three key elements in a recycled fiber plant it was shown that the answer to a widening gap of raw material quality on one side and recycled pulp quality on the other side is not to add equipment, but to use equipment with significantly higher efficiencies and good control characteristics. Only with such subsystems recycled fiber systems can stay affordable, have a high availability and ensure constant recycled pulp qualities.

The Column Flotation technology allows to reduce the flotation in a recycled fiber plant to one cell and one feed pump per loop only. Low and well controllable reject rates contribute to the a better system yield and hence a better plant feasibility.

With the Compact Dispersion a pressurized dispersion system was presented that reduces the number of rotating machines from traditionally seven or more to four only. Full control of the process is given by viscosity control of the stock exiting the screw press and by power load control by on-the-run disperser plate gap adjustment. A new speed heating concept within the disperser system reduces negative effects of heating like color reversion or COD increase and it offers ideal conditions for bleaching.

With the Fiber Roller a machine was presented that has good means of control of the washing efficiency in terms of suspended solids. At the same time this machine can eliminate a second stage thickening since it is able to thicken stock from approx. 0,7% to over 30 %

There would be more subsystems to add that contribute to the demand of todays and future recycled fiber systems. Like there is

- *P O-Bleaching*
- *high consistency hydrosulfite bleaching in a Compact Dispersion system*
- *hydrodynamic fractionation in a washer filtrate.*

However, this would have exceeded the limits of this paper and is left for presentation at a later occasion.

INTRODUCTION

The worldwide use of recycled fibers was remarkably increased during the recent years. In consequence also waste paper sources which were

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rejected in previous times had to be considered for collection to comply with the market demands. Recycled fiber mills now have to cope with deteriorating waste paper qualities while facing at least the same if not increased quality requirements for the processed recycled fiber stock. The highest demands in this respect as of today is recycled fiber stock for substitute virgin pulps for SC and LWC grades or DIP from mixed office waste meeting the quality specification of hard wood kraft pulp.

A recycled fiber plant that can generate the required stock quality from available raw material sources needs to provide better efficiencies than conventional recycled fiber plants. Typically this has been achieved so far by adding additional equipment. Such designed recycled fiber plant can become very extensive in terms of numbers of equipment used in the process. Hence, it becomes more complicated to operate the plant, its availability could be reduced and obviously it's operating cost is high due to lower yield, high energy and high chemical consumption.

The solution to the conflict of increased process efficiency and the feasibility of the recycled fiber plant is the use of equipment which efficiency is much higher than presently used equipment. The aim is to reduce the number of equipment used in a recycled fiber plant as well as to reduce its investment and operating costs. Such equipment must be reliable and its efficiency parameter must be prepared for easy and effective control.

In the following this paper presents three subsystem developments for the main process line of a recycled fiber plant that all by itself leads to simplification of the plant and at the same time provides higher efficiency and improved controllability to the process, These three subsystems are listed in Fig. 1. The paper will present the relevant equipment of the subsystems, compare it to

3 New Subsystems to Suit the Needs of a Future DIP Process

↗ Flotation
 * Flotation Column

↗ Despersion
 * Pressurized Compact Dispersion

↗ Washing
 * Fiber Roller

Fig. 1.

existing equipment and show results achieved with the equipment in mill operation or in pilot plant units.

COLUMN FLOTATION

Deinking flotation nowadays typically consists of several flotation cells in series-herein referred to as multistage flotation-where stock is aerated by venturi nozzles or diffusors before entering the cell. The nozzle or diffusor creates high turbulence that mixes air with stock. This turbulence is the important parameter for the air to ink contact probability which is required to make the ink adhere to the air bubbles. The cell body itself is designed to separate stock and ink loaded foam. The efficiency of nozzles respectively diffusors is such that 4 to 6 passes through this aeration unit are required to achieve about 90 % of the efficiency which is achievable by a deinking flotation process. This can be equally achieved by 4 to 6 flotation cells in series or by internal or external stock recirculation. Other systems than the ones described here are rarely found in paper industry.

Three years ago Kvaerner Hymac initiated a research and development program to evaluate the value of the so called Column Flotation for recycled fiber plants. - The Column Flotation was developed

Floation Column with Counter Current Flow Principle

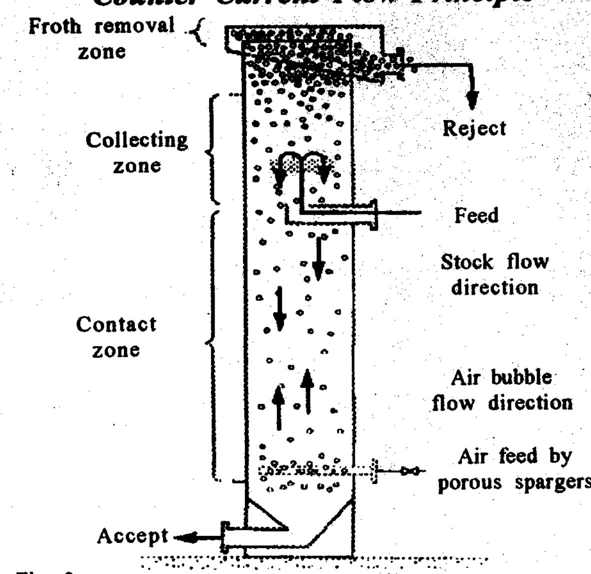

Fig. 2.

mechanical pressure excerted on the web is very high. The pressure is relieved when the web is discharged from the plug zone of the press. Therefore, a screw press may even be used as a plug screw feeder, provided that the discharge house is designed to withstand the pressure in the system.

Kvaerner Hymac's screw press, the so called Thune Press, has been re-designed for sealing the steam pressure in the dispersion system, having a design pressure of the 3 bar (0.3 MPa). Several presses are already equipped with pressurized discharge house, and no difficulties whatsoever have been experienced with this concept. A control system actively monitors the steam pressure in the system, preventing blowback situations.

KVAERNER HYMAC'S COMPACT DISPERSION SYSTEM

Combining the screw press with pressurized discharge house, along with the High Shear Mixer and the KRD, a simpler but more effective process for dispersion and bleaching has been created:

Pressurized Dispersion Systems

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* Heating Screw	* Heating Screw	
* Feeding Screw	* Feeding Screw	
* Disperser	* Disperser	

Fig.10.

Pressurized Compact Dispersion System

Fig.11

* A system with only four rotating components: Pressurized Screw Press, High Shear Mixer, Ribbon Feeder and Disperser, compared to the conventional system comprising 7 components; Pre-dewatering press, screw press, plug screw feeder, shredder, conventional preheater, infeeder and disperser. This means that Kvaerner Hymac's dispersion system has a much lower installation cost, both in terms of mechanical and elecrical installation.

* A compact system (Fig. 11), having a preheater of half the length compared to conventional preheaters, besides fewer components. Floor space requirements can be reduced, a significant benefit both for existing and greenfield mills.

* The compact dispersion gives full control on the relevant dispersion parameters as there is stock viscosity, by screw press torque control, and specific dispersion energy, by on the run disperser plate gap control.

* A preheater system tailor- made for efficient steam heating that is even highly efficient for mixing pulp and bleaching chemicals.

* A preheater with short retention time, reducing any negative thermal effects such as brightness reversion and COD increase.

FIBER ROLLER

In Fig. 12 a schematic of the Fiber Roller a new machine developed for the purpose of

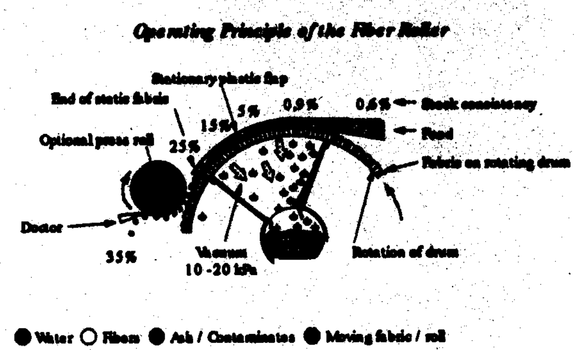

Fig.12

by Cominco Engineering Services Ltd. for the mining industry. In 1992 there where over 150 Column Flotation installations in mining industry of which 90% where supplied by Cominco. - First pilot plant trials where made with a 15 cm diameter Flotation Column, followed by a scaled up pilot plant Flotation Column of 60 cm diameter. Early 1996 the first industrial size Flotation Column went in operation in North American recycled fiber plant, installed in parallel to an existing multistage flotation system.

The Column Flotation principle is shown in Fig. 2. The stock is fed at about 2/3 of the height of the Flotation Column where it is distributed smoothly and evenly over its entire diameter. The lack of high shear forces in the Flotation Column, as they are typical for conventional multi stage flotation, prevents ink floc aggregates to break apart. In the column the stock travels downwards towards the accepts discharge. On its way down the stock passes rising air bubbles, which are injected at the bottom of the Column. During its entire retention in the Column the stock is exposed to the air. This ensures the high contact probability of air and ink.

The main air injection consists of porous spargers (patented by Cominco) which are evenly distributed over the entire cross section of the Column. The porous spargers - made from sintered metal - is fed by pressurized air of approx. 1,4 bar gauge. Air is released through the micropores of the spargers into the stock forming a dense cloud of very fine air bubbles that the stock has to pass.

Latest trials have shown that the ink removal efficiency can be increased by adding additional air into the feed pipe or the Flotation Column. The type of air injection used here is a so called Sparjet which also is a development of Cominco. The Sparjet injects air through a specially designed nozzle which creates supersonic air speeds.

The ink loaded froth collects at the top of the Column where it is removed by a rotating scraper. The Flotation Column is typically operated with foam overflow only. The froth depth respectively the rejectrate is typically controlled by the suspension level which is detected by two level transmitters at the cell. The control of the level is in the accuracy of a few centimeters while typical froth thickness is 20 to 80 cm.

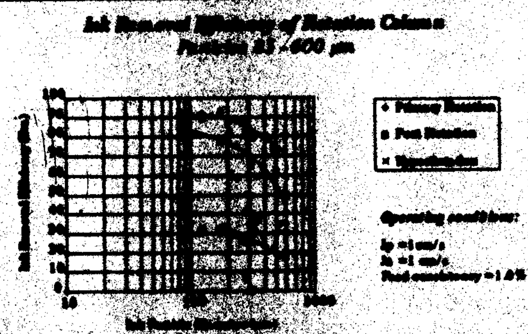

Fig.3

Fig. 3 shows ink removal results achieved by the 60 cm pilot plant Flotation Column. The raw material in this trial was North American MOW.

The rhomb shaped points show the ink removal efficiencies of one pass through the Flotation Column. Over 90% removal efficiency was achieved for ink particles below 150 µm diameter. For ink particles between 150 and 300 µm the efficiency was in the range of 55 to 80%. For larger ink particles the efficiency drops rapidly close to zero. Considering that just a few years ago it was common knowledge that deinking flotation can only remove particles up to 150 µm these results can be considered a success. The crossed points show the removal efficiency of a hyperflotation. This a laboratory flotation which is conducted to the point where no additional inks will be removed. This is to be considered the maximum by flotation achievable result. However the Flotation Column achieved better results compared to hyperflotation. The reason for this is not fully clarified. It can be the laboratory cell is just not able remove certain inks because of its different principle of air injection and its bubble size range or it is possible that surface charges and chemistry changed its effect. This is possible because the hyperflotation was not done at exactly the same time than the Flotation Column trial.

The accept stock of the Flotation Column was passed through the Column a second time in order to determine how much removable ink was left in the stock. The square points of Fig.3 show the results. In average 30% of the remaining ink could be removed. From this one can calculate that the maximum achievable Flotation Column ink removal efficiency for inks smaller 150 µm was 93 to 95% (compared to 90% achieved in the first pass). For larger inks the ratio remains about the same.

It is commonly known that the efficiency of ink removal, in particular for MOW furnishes, depends very much on the stock treatment before flotation and the process chemistry. Therefore it was of utmost importance to us to evaluate the Column Flotation Process in a day to day mill operation in comparison to a well reputed multistage flotation system. Such trials were carried out in early 1996 in a North American recycled fiber plant. The waste furnish to this plant wàs MOW.

The Flotation Column with a diameter of 1,5 m was placed in parallel to a multistage flotation system with external recirculation at each cell. The number of theoretical passes of this system was calculated to 6. The rejects of this system were fed to a secondary cell. Its accept was fed back to the feed of the system. The Flotation Column was equipped with porous spargers at the bottom as well as with optional installation points for additional Sparjets in the feed and/or at the bottom.

For each measurement feed and accept samples were evaluated by image analysis and brightness. Also the reject rate of the Column Flotation was measured. Two measurements of the existing multistage flotation system were made and are regarded as reference. Ten measurements were made around the Flotation Column. Four of them were rejected because they were purposely taken under extreme operating conditions (very low reject rate) respectively unsuitable air injection arrangement (no use of porous spargers). The results can be taken from the graph of Fig. 4.

Relative Ink Removal Efficiency of the Flotation Column in a MOW Deinking Mill compared to Multistage Flotation

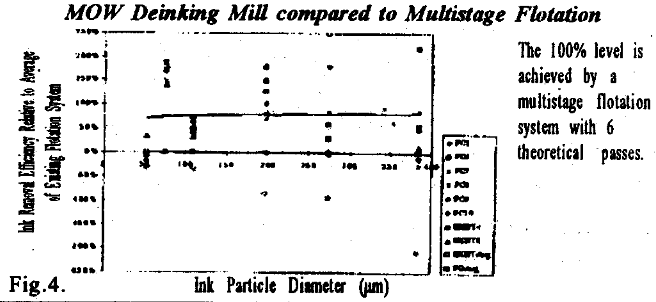

Fig.4.

A point on the 0% line means that the measured ink removal efficiency is the same as the average of the existing multistage flotation system. Its two measuring points are symmetrically located above and below the 0% line and are named Exist 1 and Exist 2. They show the actual relative deviation from the average value. In the same way the results of the six measurements for the Flotation Column are marked FC1/4/7/8/9/10. The red squares are the average value of the six Flotation Column values. Bringing this average values in a logarithmic regression leads to the curve that is located at about the +70% level. This means that in average one single stage flotation column results over the entire particle range measured in a efficiency that is 70% (relative) higher than the existing flotation.

Although the brightness gain through flotation is usually of minor importance for MOW furnishes it was measured as well in order to compare the removal efficiency for invisible inks. Fig. 5 shows that all brightness gains are on the same level between 1, 5 and 2, 5% ISO.

The next graph in Fig.6 demonstrates the reject rate for each of the measurements for the Flotation Column. It shows in each case extremely low reject rates in the range of 1, 5 to 3, 5%.

Brightness Gain of the Flotation Column in a MOW Deinking Mill Compared to Multistage Flotation

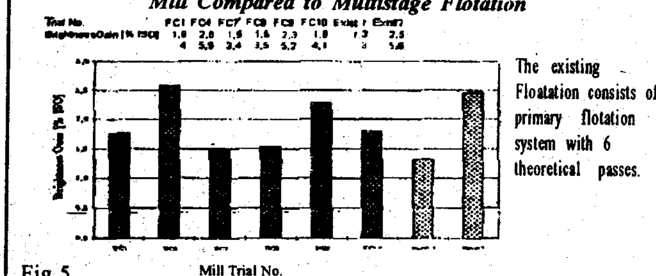

Fig.5.

Reject Rates of the Flotation Column

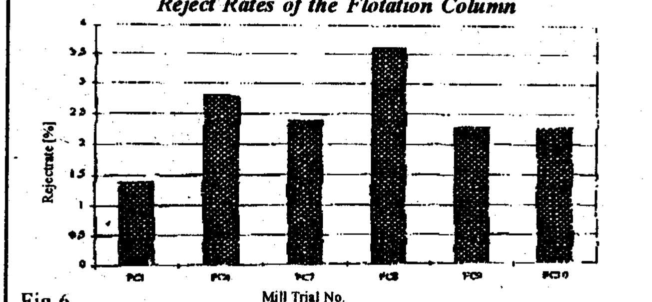

Fig.6.

Unfortunately the reject flow of the existing multistage flotation system was not accessible and could not be measured, but typically one would expect flotation reject rates above 4% for North American MOW. Therefore, the rejects rates the Flotation Column was operated at are very low. This leads to the expectation of achieving better system yields in DIP-plants when using the Column Flotation for Deinking.

During one month of continuous operation the Flotation Column proved a reliable operation. Thanks to the two point level measurement and the thick froth, the level and the reject rates could be easily controlled. Wear, plugging or deposits on the spargers were not observed.

Fig.7 shows a 3-D graphic of the Flotation Column and its main components. A Flotation Column for approx. 150 bdmt/d stock is 7m high and has a diameter of 4,3 m. The area between porous spargers and the feed is divided into sections of equal areas. It is approximately the same cross sectional area for every size Flotation Column in order to have the same flow characteristics in each size cell. Subsequently scaling up problems will be omitted. The scraper at the top of the cell is designed to guide the froth gently to the sludge gutters, which are radially arranged and lead the froth to the froth outlet of the Column. This method results in a short traveling distance for the froth until removed. This prevents remixing of froth with the stock.

COMPACT DISPERSION

Dispersion is a process of reducing the particle size of contaminants. The high treatment temperature in the dispersion system also effectively eliminates the presence of bacteria and fungi in the stock - exceedingly important for end products being used for food-packaging etc. (e.g. folding boxboard). Furthermore, dispersion offers the right temperature and ideal mixing devices for bleaching.

In most processes, the stock consistency is too low to ensure economical heating of the stock, i.e. the stock consistency must be raised. Furthermore, dispersion of contaminant particles is favored by high consistency. Hence, in this context, a dispersion system comprises dewatering, heating and dispersion itself.

HEATING

Traditionally, pulp heating from system temperature, some 40 - 50-°C, to dispersion temperature, some 90-120-°C, is performed using slow rotating screw conveyors with direct steam injection. These are usually termed preheaters. The preheater is usually designed for a residence time of some 3-5 minutes, bringing the total length of the preheater up to some 11 meters, along with a diameter of some 1 to 1.7 meters, for a system having capacity of 300 - 400bdmt/d. Although conventional preheaters are well established, no studies appear to have been published on steam heating of pulp particles.

The temperature (T) profile of a solid sphere with radius r, can be determined using the Equasion in Fig. 8.

- in which p is the material density, t is time, k and Cp are the thermal conductivity and specific heat capacity respectively. From the Equasion can be seen that as the particle radius diminishes, so does the required time for heating.

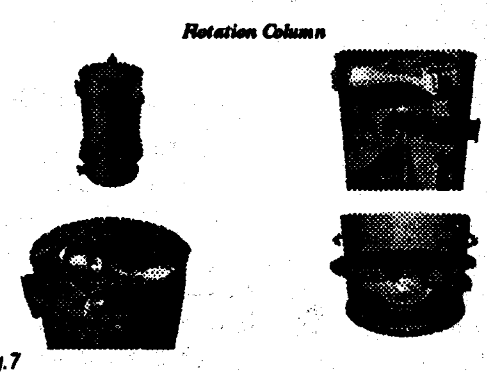

Fig.7

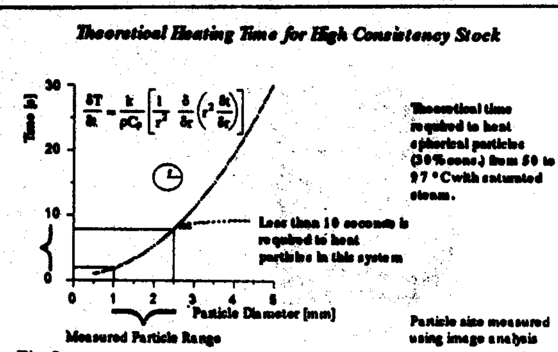

Fig.8

By applying Eq. 1 one can determine the required time to heat an arbitrary spherical particle having the properties of papermaking pulp of 30% consistency, from 50 to 97-°C, using condensing steam, cf. Fig.2. As can be seen from Fig. 2, particles having a radius of some 1mm, just some 2-3 seconds are required to reach a temperature in the center of the particle of 97-°C. In practice, such spheres obviously do not exist. In fact, heating may be performed at a much higher rate as the pulp particles, having an equivalent radius of 1-mm, are exceedingly penetrable in that fibers are disoriented.

In essence, the time required to reach a given temperature increases with the square of the radius of the particle. Hence, small particles will very rapidly reach the desired temperature. Basically, there are three requirements for efficient pulp heating: 1) The pulp particles must be small (some 1 mm radius is suitable). 2) There must be sufficient contact between steam and pulp particle, i.e. mixing is essential. 3) The steam must be saturated (or close to). It may be concluded that steam heating may be performed using significantly lower residence time than in conventional steam heated screw conveyors comprising that sufficient pulp particle dispersion and particle/steam mixing are ensured.

To assess the possibilities to perform heating at exceedingly short times, we conducted some trials in which steam was injected into the center or a high speed rotating mixer, obtaining a pulp residence time of less than one second. The result is depicted in Fig. 9. Here, the feed pulp had a temperature of 20-°C, and the pulp consistency was 30%. The discharged pulp had a temperature of some 95-97-°C.

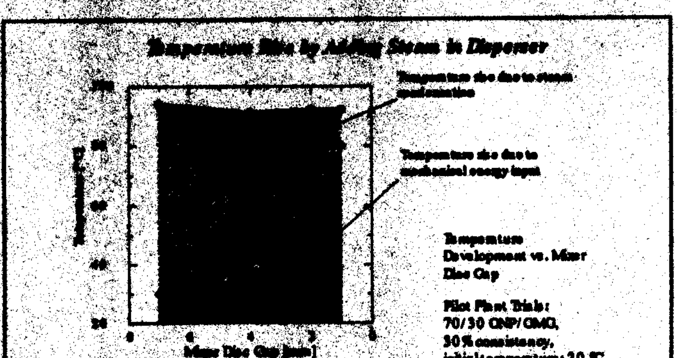

Fig.9

These trials actually verifies that conventional preheaters are not optimized in terms of cost/benefit, however serving the purpose of heating the pulp. Furthermore, there are some inherent deficiencies with the concept of using slow rotating, long residence time, preheaters: The long stock residence time in conventional preheaters (some 3-5 minutes), a thermal brightness drop can be expected for mechanical fibers. Further, the slow rotating screw of the preheater implies insufficient mixing of the pulp, significant when bleaching in dispersion systems. Trials that we have performed in our pilot plant with hydrosulphite bleaching have shown a difference in brightness increase of more than three points ISO between adding hydrosulphite in a conventional preheater compared to in a mixer.

A NOVEL CONCEPT FOR PREHEATING

Kvaerner Hymac adapted a high consistency high shear mixer - a well proven machine for mixing purposes for high stock consistency - for the purpose of heating. It is called Speed Heater.

The Speed Heater is a high speed rotating device (500-600 RPM), in which the entering pulp is very efficiently shredded, and the high turbulence generated, makes the machine ideal for mixing purposes fulfilling all the three requirements mentioned above. Hence, steam is mixed with pulp at a very high efficiency, along with bleaching chemicals if necessary. The residence time in the Speed Heater is some 10 to 20 seconds, significantly more than required for steam heating per se. However, the actual residence time chosen is suitable for reductive bleaching (e.g., hydrosulphite) at elevated temperatures, hence the Speed Heater even serves the purpose of being an efficient chemical mixer.

A NOVEL CONCEPT FOR DISPERSION

In case of pressurized dispersion, a plug screw feeder is conventionally used to seal against the steam pressure, whereas dewatering is frequently being performed using screw presses. In screw presses, a pulp plug is formed at the very end of the screw press, in the so-called plug-zone. In this zone the web is compressed to high consistency, and the mechanical pressure excerted on the web is very high. The pressure is relieved when the web is discharged from the plug zone of the press. Therefore, a screw press may even be used as a plug screw feeder, provided that the discharge house is designed to withstand the pressure in the system.

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Fig.10.

Pressurized Compact Dispersion System

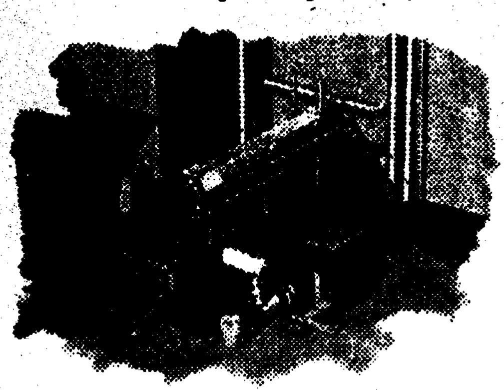

Fig.11

* A system with only four rotating components: Pressurized Screw Press, High Shear Mixer, Ribbon Feeder and Disperser, compared to the conventional system comprising 7 components; Pre-dewatering press, screw press, plug screw feeder, shredder, conventional preheater, infeeder and disperser. This means that Kvaerner Hymac's dispersion system has a much lower installation cost, both in terms of mechanical and elecrical installation.

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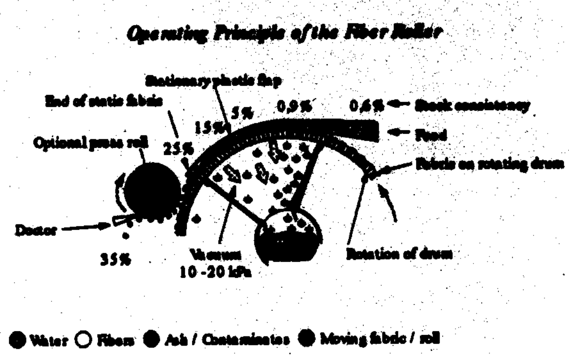

Fig.12

stock washing is shown. It consists of the following elements;

* Headbox
* Stationary plastic flap
* Rotating drum with fabric
* Cleaning shower
* Suction box
* Press roll which acts also as pick- up roll
* Screw conveyor for transport of washed stock (not shown)
* Fan for the vacuum and the water separator (not shown)

The stock is fed via a headbox at low stock consistency between a rotating perforated drum with fabric and a stationary air proof plastic flap. The dewatering takes place towards the center of the Fiber Roller aided by a low vacuum of 10 to 20 kPa (0,1-0,2bar). When the stock consistency has reached 10 to 15% the stock starts to roll and dewatering continues untill a consistency of some 25% are reached. Then the fiber rolls leave the plastic flap and can be discharged. When higher stock consistencies are desired the Fiber Roller can be equipped with an additional press roll that brings the consistency to 30 to 40%, depending on the operating conditions.

The washing principle can be explained by a model as drawn in Fig. 13.

* The stock is fed between a stationary plastic flap and a moving wire. Water, ash, fines and small contaminants leave the area through the wire. A fiber mat tries to form a filter mat on the wire.

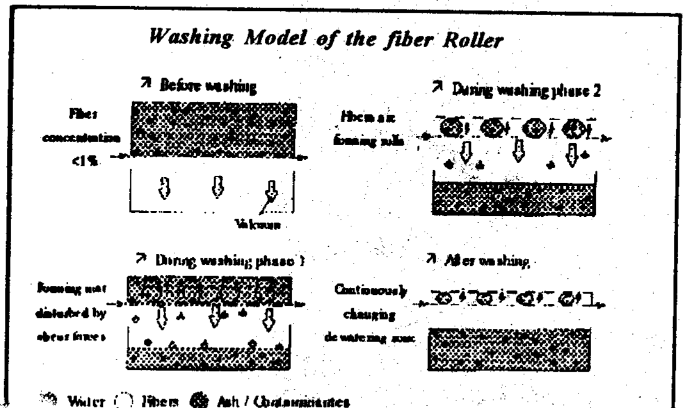

Fig. 13.

* The filter mat is continuously broken up by the shear forces generated by the relative velocity of moving wire and stationary plastic flap. This is enhancing the removal of small suspended solids.

* When approx.10% stock consistency are reached, the shear forces cause the fibers to roll. This allows further removal of small suspended solids as well as further dewatering.

OPERATING AND CONTROL CHARACTERISTICS OF THE FIBER ROLLER

Fig.14 shows the ash reduction of the Fiber Roller versus the speed of the machine. The speed range is 20 to 80 rpm corresponding to 70 to 280 m/min. The three curves represent different feed consistencies. It can be seen that at a feed consistency of 0.84% a good controllability in the range from 55 to 85% is possible. With lower feed consistency this range is moved up and vice versa. 30% control range is a good figure for the controllability of the accept ash content. Still it is desirable for partial washing to move the controllability towards deashing efficiencies between 30 and 6%.

The influence of the machine speed and feed

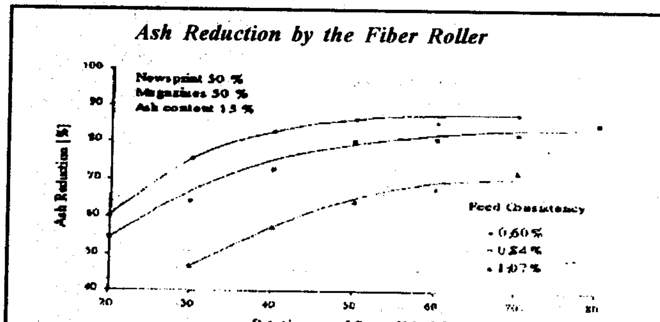

Fig. 14.

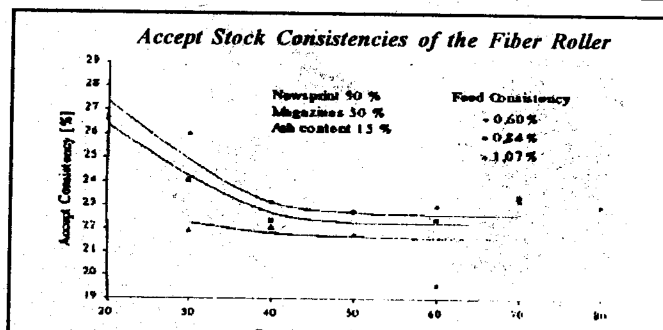

Fig. 15.

consistency to the accept stock consistencies is shown in Fig. 15. At low Fiber Roller speed accept stock consistencies of up to 40% were achieved. At 50 rpm the curves flattens out a level of 23 to 26%. It is believed that stock consistencies of 30%. plus, can constantly be achieved with a pressure variable press roll and an optimized roll cover.

At present the research work emphasizes on broadening the control range for ash removal. Different types of fabrics and optimized headbox and suction box design make room for such optimizations.

Fig. 16 shows a workshop picture of the Fiber Roller without press roll.

Fiber Roller

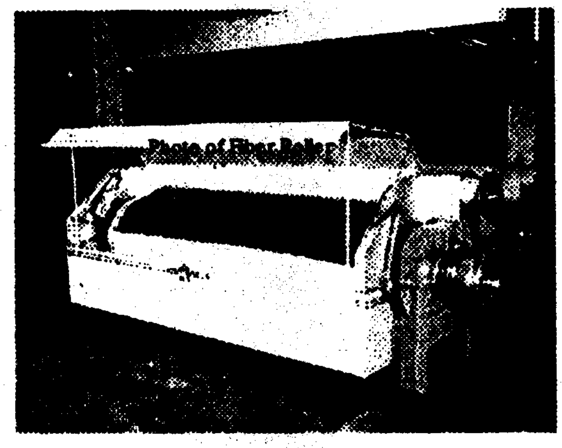

Fig.16

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