Paper technologies: past, present, and future

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Abstract

The last 25 years of pulp and paper industry have been marked by significant events, among others the increased use of recycled fibres, the so-called dioxin crisis, and a strong effort to tackle environmental concerns. In various aspects, the pulp and paper industry has shown a leadership role. In the same time period many advances were effected in process technology, from the twin-wire generation to increased paper machine speeds, and new coating technology, use of calcium carbonates, etc. The most significant changes have been outline with a special focus being placed on the present status of the industry, the next changes to be expected and how it has been, is, and will be supported by a somehow re-structured international R&D. Special emphasis will be placed on European R&D.

INTRODUCTION

Paper.... What a wonderful product ! Most people know about the invention of the paper by the Chinese culture, as most printers know about the perfecting of the letterpress process by Gutenberg at the beginning of the 15th century but few, even papermakers, would know that next year the

paper machine was invented by a Frenchman, Louis-Nicolas Robert, in 1799 (**Figure 1**) ! In 1999, France will celebrate the 200 years of the invention of the paper machine with many special events. One of these will be the presentation of a virtual paper machine at the Palais de la Découverte, in Paris. This virtual paper machine is based on the new concept by Valmet (**Figure 2**) which shows how much the technology has evolved in 200 years.
Paper is key for civilization development and growth as mass media printing does not exists without mass media production of paper. In essence, no paper no print, but also no Gutenberg bible, no 50 years of TAGA. As it would take well over the limited allowed time - and pages - to treat such a vast topic of paper past, present and future, I will merely review the main milestones of the paper industry for the last 25-50 years, with an emphasis on the last 25 years. From there, I will have a look at the present and sees what lies in our uncertain and mixed future of information technology, as one has to know the future to understand the present, and understand the present to foresee the future. I have attempted elsewhere (**Mangin, 1997, 1996**) to explain that, at least for the next 25 years, information technology will somehow try to co-exist with a still predominantly paper-based society.

Making such a review about papermaking is a complex challenge because papermaking is complex. It involves many industrial areas, from tree growing and the new biological trends, to chemistry, chemical engineering, process technology, environment, and even society trends as a far a recycling, packaging, and even reading habits are concerned. As it is not feasible, in a single article go all over these aspects, following key areas have been presented:

- Pulping process, including bleaching
- Papermaking process including finishing such as calendering, coating, but also process on-line control

- Recycling, including recycling technology
- Environment
- Research&Development

The pulping processes

For pulping, the main change has been moving towards an increased used of mechanical pulps. In mechanical pulping the old stone groundwood process which gave excellent opacity to the paper due to its relatively high fines content has been replaced by pressurized groundwood (PGW), thermo-mechanical (TMP), and chemi-thermo-mechanical pulping (CTMP).

The pulp industry has also seen an increased use of hardwood, for instance poplar, and even in the last years Eucalyptus from southern countries (Spain, Portugal, Brazil, etc.).

In high yield pulping, the recent dominant technological advances has been Alkaline Peroxide Pulping (APP) with aspen or poplar. APP can produce bleached high yield pulps, with yield over 90 %, at high brightness levels, up to 85–86 % ISO. Mechanical characteristics are comparable to those of bleached hardwoods chemical pulps obtained at a much lower yield (48–50 %). The process runs at industrial scale, the effluents being evaporated, concentrated and burned making the "zero effluent mill" a reality.

For thermo-mechanical pulping (TMP) process at low energy consumption, mention should be made of the RTS process (Retention, Time, Speed) from Andritz Refiner Systems. In the RTS process, steaming of wood chips occurs in a very short time, in about 30 seconds but at an elevated temperature of 150°C-160°C. The stage is followed by defibrating in a disc refiner at high speed, about 2300 rpm.

In the Thermo-pulp process from Sunds Defibrator , the second stage of the TMP process is also carried out at high temperature, around 160–170°C, during a few seconds.

Finally, the Bivis process originating from a CTP-CLEXTRAL venture, allows to treat annual vegetal fiber resources. In the first stage of the Bivis, fibers are extruded at low speed (about 350 rpm) through a screw system with opposing screw profiles. Feeding fibers through the system creates different pressure zones where fibers are gently treated and thus most of their mechanical properties preserved. The system is widely used to produce, among others, paper money.

In chemical pulping processes, the main areas are:

1. Extended or modified kraft cooking permitting to reduce the bleaching costs (chemicals) and his environmental impact.
2. Bleaching sequences without chlorine. After a several years controversy to know which of ECF (Elemental Chlorine Free) or TCF (Totally Chlorine Free) bleaching sequence was to win, the best compromise between pulp quality, costs, yield, and environmental impact is in favor of ECF sequences. The combination between chlorine dioxide and ozone seems be the best solution to reduce the bleaching costs and the effluents AOX content.
3. Large reduction of the water consumption for the manufacture of bleached chemical pulps : 10 – 15 m^3 per ton of pulp compared to 60 – 80 m^3 per ton of pulp required 10 years ago. This result has been obtained by circuits closing. Now the zero effluent becomes a reality.

For the future, one can foresee:

- a zero effluent chemical pulp mill,
- more selective pulp manufacture processes,

- use of bio-technologies in pulping and bleaching,
- enzymatic treatments : use of ligninolitic enzymes to reduce chemicals and develop the pulps strength,
- clones selection of trees more suitable for the pulps manufacture,
- transgenic trees at modified lignin or lower lignin content, easily extracted in order to increase the pulp yield, and
- fiber characterization permitting to establish relationships between the fiber properties and the papers properties and thus predict the behavior to the pressing and drying during paper manufacture on the machine.

To achieve such results, there will also be a need in some fundamental studies such as:

- investigating topochemical modifications of the fibers as a function of delignification
- finding the effect of oxygen delignification on the residual lignin and residual lignin-carbohydrate complexes of chemical pulps
- developing alternatives or improving of fibers separation in mechanical pulping to still reduce the energy consumption and produce pulps with fiber distributions that will provide better strength properties in paper
- investigating pulp aging and yellowing mechanisms.

The papermaking process

The paper machine and technology around the paper machine have drastically evolved in the last 50 years. At a first glance, the more dramatic improvement is the doubling of the speed in 30 years; this being achieved while keeping the same length of the paper machine. Such a doubling has only been possible through many step improvements in the process. One should notice that changes will, for a mature industry, still exist also technology, in the paper industry, moves at a slower pace than in the printing industry. It can be expected that paper machine speeds will still increase, up to 2500 m/min while still becoming shorter than today. Valmet will be introducing in June 1998, its new paper machine concept for the year 2000 (Valmet, 1998). Forming paper at such speeds is possible using formers with high hydraulic pressures and no open draws throughout the entire paper machine. Impulse technology with high temperature pressing and impulse drying, and/or high velocity-high temperature air or superheated steam drying will also be key technological improvements that will allow a further shortening of the paper machine length with increased speed. Throughout the entire papermaking process new sensors and new control strategies will then guarantee that the paper is not only better but more constant in quality. From Nicholas Robert to present, how the future has been prepared is now part of history.

Pulp preparation

After raw processing of the pulp, either by cooking or mechanical treatment, it needs to be refined. Refining the pulp was done with conic refiners already before 1950. The nowadays common double disk refiners were introduced in the early 1960. Conic refiners are still in use and even had a renewal of sorts in the last 15 years.

After refining pulp is cleaned. In pulp preparation, to the development of screening technology from holes to slots at reducing sizes while maintaining efficiency with different blade designs, one should add the development of hydro-cyclone cleaners, among which the Giroclean. The screening/cleaning technologies were often developed from fundamental flow studies.

The wet-end part of the paper machine has seen the open type head boxes move towards the closed type head boxes early on, before 1950. The hydraulic head boxes, operating under pressure, were introduced in the 1970s while recently, in 1992, the hydraulic head box with profile control by dilution was introduced both by Valmet and Allimand based on a concept developed at EFPG (the pulp and paper engineering school next door to CTP!)... it was normal that the re-invention of the paper machine came back to its origins, somewhere in France. The reasons for these various modifications is of course formation. The last concept, based on CD dilution control directly at the head box should drastically improve paper machine CD profiles and overall formation.

Wet-end forming

The Fourdrinier paper machine has had a long life since its invention about 2 centuries ago... and will still be in use for quite some years when one considers the special paper grades. For water removal, the drainage rolls used initially on Fourdrinier paper machine were replaced around 1970 by new drainage devices, plastic foils. Looking at the development of various twin-formers, in which the pulp is drained between two wires, it comes as a surprise that the first twin wire former was developed in 1956-60. As said before, the paper industry is rather conservative. It takes time from development to implementation. The initial twin-wire formers concept was then followed by various concepts such as top formers, basically rebuilds from old Fourdrinier paper machines, vertical twin-wire formers, hybrid formers, and eventually the so-called gap formers in the 70-80 decade. The main purposes for further developing these machines was speed increase but also reducing the paper two-sidedness by draining water from both sides of the sheet. Two-sidedness is still an issue although it has constantly improved over the years: both sides of the sheet now look more similar than ever before.

Pressing

Pressing is the consolidation stage of the paper sheet. Plain presses, i.e. just pressing between plain rolls, was not very efficient but sufficient for the slow machine speeds in the years 50-60. At about the same time, vented nip presses and drilled presses were perfected in order to improve water removal but paper was still unsupported between the presses. This changed around 1970 with the advent of 3 nip presses with no draw arrangement which increased water removal efficiency resulting in a further machine speed increase. The 3 nip arrangement also improved two-sidedness. Realizing that pressing was a key part in the sheet formation/consolidation processes engineers went back to the drawing board. Pressing pressures increased and the nip of the presses extended, as can be seen in the so-called extended nip press and various shoe presses design. Eventually engineers realized that combination of heat and pressure still further improved the water removal... but we were already in the 80s.

Some words should be said about the felts, an important part of presses as the felts role is to carry the water removed from the wet paper out of the press section. The industry moved from wool felts used before the 50s to synthetic felts in the 70s. Similarly, the press roll coverings moved from polyurethane, around 1980, to ceramic in the 90s.

Drying section

Initially drying sections were open. For the non paper maker, let us say that the drying section is the part of the paper mill where it is usually very hot. For energy preservation reasons, the drying sections were closed in the 70s... but are still, even nowadays and also they should, not always operated as such.

As far as paper machine speed is concerned, the drying section is the key factor limiting paper machine speed. No wonder then that many designs were tried to improve drying efficiency. Following is but a list of the most important technological changes. The gas infrared technology was tried early on in 65, then with electric power in 81. The first flotation air dryer, used for pulp machines, were commercialized in the 70s. Some years later attempts were made to dry the sheet by blowing hot air through the fiber network, i.e. through the sheet. The technology succeeded in the tissue market. Further trials for other grades than tissue were still performed in the early 90s. Recently, the gas heated dryer with only 2 cylinders installed in a whole drying section, has shown to improve drying efficiency. It is still in limited use: 2 installations in the USA, and yet no European installation. As a new technology Condabelt is just coming.

For the future, one should keep watch over impulse drying were the paper sheet comes very briefly, tens of millisecond, in contact with a superheated roll at high pressure. The technology has promises but still needs to prove its usefulness in every day utilization.

Automatic control

Control of the process, directly on the paper machine, is critical for obtaining an uniform quality of the paper sheet. Early in 1952, the first basis weight sensor was installed on a paper machine. It was a big step forward for paper quality control and uniformity. It was soon followed by a flurry of other controls. Let me remind here the most important such as cross-direction control of both basis weight and moisture, in 1963, followed by caliper control, color, ash, smoothness, in the 70-80s.

The advent of the computer helped the paper maker to close the control loop. Closing the loop was effectively achieved as early as the 70s for machine direction control of both basis weight and moisture, and for CD (cross direction) in the 1980s. Color control was finally achieved in 1985 and so was formation. Sensors for various paper properties are still under development. The main idea for full control management is based on a distributed control system, a principle already introduced in 1980. For the future, the goal of papermakers is the total process visibility. It looks like this goal will be achieved in the years to come. That is a true challenge for R&D.

The paper machine of the future

Some words on the future of the paper machine: definitely higher speeds and still shorter paper machines will be made possible by following technologies: a former with high hydraulic pressures, no open draw throughout the entire paper machine, high temperature pressing, may-be even impulse pressing but surely impulse drying or high velocity, high temperature air or superheated steam drying. Finally the paper machine will be a fully controlled process through the implementation of new sensors and new control strategies.

Finishing and calendering

Once manufactured the paper needs to be surface treated to improve its printability properties. The paper surface treatment is either achieved through calendering or coating. Calendering is basically an ironing of the paper surface, and it is more or less what was done in the first conventional calenders. These consisted of a stack of metal rolls were the web was ironed. Conventional calendering results in a smooth paper with varying density through the sheet thickness.

The supercalenders allow higher gloss, and higher smoothness to the paper surface. It is an off-machine operation which application increased in the 80s. However, supercalendering has been a kind of a bottleneck in papermaking with 2 to 3 supercalenders needed to keep pace with a paper machine. New calendering machines were then designed to operate at high pressure and high temperature. On-line soft and hot calendering is still under development but industrial installations are more and more common. At the high temperature range, temperature gradient calendering, where the sheet is pressed between steel cylinders at temperatures around 210°C may find niche market applications, mainly in the board industry.

Coating

Coating is a paper surface treatment where a layer of minerals pigments mixed with various binders and/or polymers is applied to the paper to create a smooth uniform most often glossy surface. The brush coating developed early on in the 20s is still used for special high quality coated paper grades. Due to the time of implementation of technology in the paper industry, consolidation of coating technology : moving from roll coaters to blade, air-knife, and eventually short-dwell has taken decades. For coating formulations, the big recent trend has been to use calcium carbonates instead of clay. An increase use of synthetic lattices has also improved the coated paper quality. New styrene-butadiene blends include materials designed to run at high solids content for rapid immobilization on the paper surface. Finally one should note that coated paper basis weight have steadily declined over the years ; nowadays we even see ultra Light Weight Coated, sometimes called LLWC paper.

Wastepaper recycling

Recycling is an old tradition of the paper industry ! The first papers were manufactured from old rags, and wastepaper has always been a source of fibers for the paper industry.
Recycled fibers are one of the main sources of fibers for paper production in several countries. The graph shown in **Figure 3** gives the utilization rate (UE), -which is the amount of recovered paper used divided by the amount of paper and board produced -, of wastepaper in some of the main paper producing countries. For instance, in France 53% of fibers used in papermaking have a recycling origin. In the USA, the number is slightly above 40%. It should be noticed that the utilization rate depends on the grade of paper produced. For instance, -see **Figure 4**-, in France the utilization rate has been very high in gray and brown grade packaging papers, a strong increase has been observed with the development of deinking for newspaper, but it remains rather low for fine papers.

Some history... Wastepaper was firstly used as a substitute of virgin pulp. As clean industrial waste papers, free of contaminant were available, they were used without any particular equipment and introduced in the pulper instead of virgin pulp. With the increase of wastepaper consumption, these "white brokes" cannot be supplied in sufficient quantity and paper containing a lot of products added during the converting process or the use of the paper. These "products" are considered by people involved in recycling (recyclers?) as "contaminants" and the main progresses of the recycling technology were related to the improvement of the removal of these contaminants

Deinking technology

Deinking is a sophisticated way of recycling, high grade papers can be produced using this technique; lower grades can be manufactured from brown grades. For instance, by using deinking technology, white grade papers can be produced from post-consumer or post-industrial wastepaper. This means that not only the components which cause a reduction of brightness - here the inks - must be removed, but also that all the additives used during printing, converting, and using the paper must be removed. From the recycling point of view these additives are contaminants. They include various grades of adhesives such as binding materials, labels, tapes, staples, plastic films, inks, varnishes, and all the components of the pulp which cannot be used to produce paper. In some cases fillers must also be removed while in virgin pulps the papermaker add these fillers to provide specific properties to the paper sheet.
For 25 years important changes has been observed in the deinking technology as well as regarding the design of the flotation cells which are the key devices of deinking as regarding the conception of the process.

Flotation consists in removing hydrophobic particles, particularly ink particles, by floating them up to the surface with air bubbles. Flotation aids are used to improve the attachment of ink particles to air bubbles. The first deinking cells were similar to those used in the mining industry. Nowadays, various devices designed by machinery suppliers are proposed in order to improve air mixing and foam removal. **Figure 5** presents a basic single-loop conventional deinking plant.

The flow sheet corresponds to the mills producing de-inked pulp for newsprint or the back layer of multiply board from sorted wastepaper. That was the structure of most mills 10 years ago. Wastepapers are defiberized in a medium consistency pulper, diluted with water at 15 to 18 % consistency. After dilution, coarse screening removes large contaminants such as plastic films and wet-strength papers. High density cleaning removes heavy contaminants such as staples and sand. Hole screening and slot screening are performed at medium consistency, up to 4%. Then the pulp is diluted down to between 1 and 1.4 % consistency and submitted to flotation. Cleaning stages, either heavy or light, take place after flotation, generally after a complementary dilution down to 0.7 %. A fine slot screening stage can be implemented after cleaning, then the pulp is thickened on a disk filter.

The white water is reused for dilution, in the various stages of the process. After the filter, the pulp is stored or diluted with water from the paper machine.
The process can be completed by hot dispersion in order to improve pulp quality or by washing equipment to remove fillers and fines to produce pulp for tissue paper.
The production of higher quality pulp requires multi-stage deinking as illustrated in **Figure 6**. Please note the bleaching stage that might become more common in the next years.
Some modern mills producing market wood free DIP (de-inked pulp) from office wastepaper have more sophisticated plant with 3 or 4 loops : 3 flotation stages, 2 or 3 bleaching stages, 2 hot dispersion stages, 3 process water treatments.

Brown grades recycling technology

Recycling lines for producing packaging papers and particularly corrugated are very simple : continuous pulping, various devices for coarse screening, high density cleaning, deflaker or secondary pulper, screening, refining or hot dispersion, the cleaning being implemented in the approach flow of the paper machines.

Recycling technology evolutions

Fractionation of the pulp was firstly used to reduce energy consumption in the sense that after fractionation only the long fraction is refined: this saves energy. Fractionation has been also used to improve contaminant removal as the contaminants are concentrated in the long fraction on which the process, including hot dispersion, is focused. In some cases, pulp fractions are used separately, the cleanest fraction in the top liner and the other in the back liner.

The modern recycling lines have separate water loops for stock preparation and flow behavior before arriving to the paper machine. The removal of contaminants is performed in the stock preparation loop by screening with "improved", from standard process lines, technology. In North America, technology improvement merely includes the implementation of a light additional cleaning stage.

Hot dispersion. Dispersion at high temperature was firstly used to disperse bitumen when recycling OCC (old corrugated containers) and latter to disperse other contaminants such as wax and hot melt glues. As dispersion does not remove contaminants but ... disperse them in the pulp, it may induce detrimental effects such as deposit in the paper machine. Due to the progress achieved in cleaning and screening efficiency, hot dispersion is now questioned. In white grades, hot dispersion was early proposed to disperse hot melt contaminants and, since around the late 1970s, to improve paper visual aspect by dispersing residual ink and specks at the end of the process. With the development of two stage deinking process hot dispersion has become an important stage between flotation and post flotation. The future of hot dispersion is mainly related to the improvement of the deinking technology as both high speed dispersers and low speed kneaders are proposed to improve ink detachment, mainly before post-flotation. Various dispersing and kneading technologies are now proposed. The choice of the more efficient one is presently subject to debates, the combination of various technologies in order to combine the advantages of each one is often proposed.

New applications, such as microbiological decontamination by using chemicals in a kneader are developed and will probably be an important topic for recycling technology in a near future.

Cleaning is a technology very common to various industry but a key technology in the paper industry. Conventional cleaning technology which has been designed for the removal of heavy contaminant is also called forward cleaning. It is efficient to remove contaminants with a density higher than 1 such as metals, sand, and some varnish particles. The technique has also been experimented and proposed to remove toner ink after agglomeration with appropriate chemicals.

The increase contamination of wastepaper with light weight contaminants such as adhesives, hot melt book binding, various polymer foams (styrofoam), plastics, etc. has lead to development of specific cleaners such as the reverse and through-flow cleaners. CTP has here contributed to the development of a rotary cleaner, the "Gyroclean", famed as the most efficient of this type. It has been developed by Lamort after basic research performed in the 1970s both in CTP and EFPG. The development of efficient screening technology such as fine slot screening is now competing with cleaning.

Screening consists in removing contaminants by keeping them on a screen while fibers go through openings, either slots or holes, in the screen. Early on, screening devices

were open vibrating screens. Nowadays, screens are closed and pressurized to increase their capacity and efficiency.
In screening technology, machine suppliers have made large contribution to the improvement of contaminant removal with the development of contoured fine slotted screens down to 0.15 mm and even 0.10 mm openings.

Bleaching has become an important stage of the recycling process to produce high quality de-inked pulp. Conventional bleaching without lignin removal like hydrogen peroxide, sodium hydro-sulfite, and then FAS are widely used both in mill producing wood-containing and wood-free de-inked pulps. Peroxide bleaching is often combined with hot dispersion between 2 deinking stages as such procedure has a synergetic effect towards ink detachment.
Ozone bleaching and peroxide under oxygen pressure are now proposed in mill producing wood-free DIP for color stripping of dyed papers and bleaching of brown fibers.

Bio-technologies ? A lot of research work is in progress.
Some research deals with the improvement of drainage properties but most of it is devoted to deinking. Large R&D programs initiated both in Europe and North America particularly aim to improve the detachment of ink known to be difficult to remove from wastepaper grades as different as offset newspaper and laser printed papers. Industrial developments are expected in a near future.

Paper and the environment

Environment is an area were the paper industry has been very active and effective in the last 25 years. The paper industry has even be a kind of leader in the field but there is still work to be done. While production has been steadily increasing, contaminants produced by the industry have been steadily decreasing but also the water consumption per ton of paper produced. Figure 7 presents a graph based on an arbitrary index of 100 for the year 1970, for France you can appreciate the reduction of environmental impact throughout the years.

In the recent years, the dioxin have been the focus of interest in the paper industry. Dioxins are mainly chlorine derivatives such as tetra-chloro-dibenzo-dioxine, proven to be highly dangerous for human health even in extremely small quantities. Once these minute quantities could be detected by the development of sophisticated instruments, the dioxin crisis started. Reducing dioxins has implied a change in bleaching sequences that we have seen previously. Most recently, other industries are under the scrutiny of the governments. Questions are being asked about the dioxin content of sludge from deinking plant. It is, for the papermakers, something to follow very closely.

For the last 25 years, organic matters in effluents and suspended solids have been drastically reduced. Mill effluents have also been reduced and the industry is working towards zero effluent, a process which is already achieved in the production of lower paper grades but far from being achieved in all paper grades. The R&D centres from the paper industry are working on it.

R&D research needs for the future.

Such a presentation on the status of the paper industry has to conclude on some R&D needs. My list is not exhaustive but corresponds to the main R&D needs as perceived from the European standpoint (CEPI). However, these needs are not that different from what happens in North America although in Canada paper research has been reduced, in the industry, to below critical levels. In Europe, R&D efforts are around 0,7% of the industry turnover with a willingness to increase it to 1%. It is however not always clear what a company will charge to R&D.

As far as *fiber resources* are concerned, areas of high research interest include the development of models and techniques to predict fiber properties from standing trees, also the finding the best use for thinnings and mature tree species for different paper products. The fifth European framework program will allow the paper industry to look into the economical potential of annual fibers as a papermaking raw material. Methods to determine the recyclability of paper and board but also looking into the recyclability of fillers and pigments. A fundamental understanding of the structure related properties of papers and paper coatings is desirable to permit the development of chemicals to modify such properties.

As previously said, *environmental R&D* still represents a high priority. Some of the main challenges are the development of techniques to close mill systems, the so-called zero-discharge concept. One way to improve product design to reduce all material usage and thus minimize waste volume. The industry also needs better methodologies to describe and articulate the fate of the various compounds discharged in mill effluents and their effect on the environment. It has impact on a possible, to some extend, standardization of Life Cycle Analysis methodologies.

In the *pulping, bleaching, and recycling* areas, the main challenges will be to investigate the topochemical changes as a function of delignification. Basic studies to develop alternatives or improvements of fiber separation in mechanical pulping that would reduce energy consumption and produce pulp with a controlled fiber distribution providing better strength properties in paper. The industry still needs new technologies to bleach mechanical pulps at high brightness levels. In recycling, the development of new ink separation and improvement of techniques not based on flotation or washing: screening, membrane technology for instance. Finally biotechnology will have a word to say in both bleaching and pulping... good research to be performed here.

Papermaking still holds many challenges for the future. Important ones are the control and prevention of biological and organic deposits in the papermaking process that will occur while closing the systems; there may-be a practical limit on closing the mill. There is still a need to know if it is zero effluent for all grades or not. Paper quality is yet a factor of interest and there is a need to develop better surface treatment and coating techniques. On-line coating at very high speeds needs a better understanding of the coating rheology and how to affect it. Finally, as we have seen, coating coverage is going down but the industry wants to maintain the printability characteristics of the paper... that's a challenge that might interest many in the audience.

Paper, as said in my introduction is a wonderful product but it also proves to be a very challenging one.

Acknowledgements

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Literature Cited

Mangin, Patrice J.

1996, The future of print-on-paper in an electronic media based communication world. New technologies, new printers, new markets, Graphitec, Paris (published in french in La Papeterie, 198, 40-42, April 1996 and no 199, 64-65, May 1996).

1997 The new world of printing, 8th International Business Planning Conference, September 10-12, 1997, Paris, France.

CEPI - Confederation of European Paper Industries

January 1996, The European pulp and paper industry and its research needs, 250, Avenue Louise, B-1050 Brussels, Belgium. Fax (+32) 2 646 813.

Valmet - XI Valmet Paper Technology Days

1998, Kari Pantsu Ed., Valmet Corporation, Rautpohja, PO Box 587, 40101 Jyväskylä, Finland.

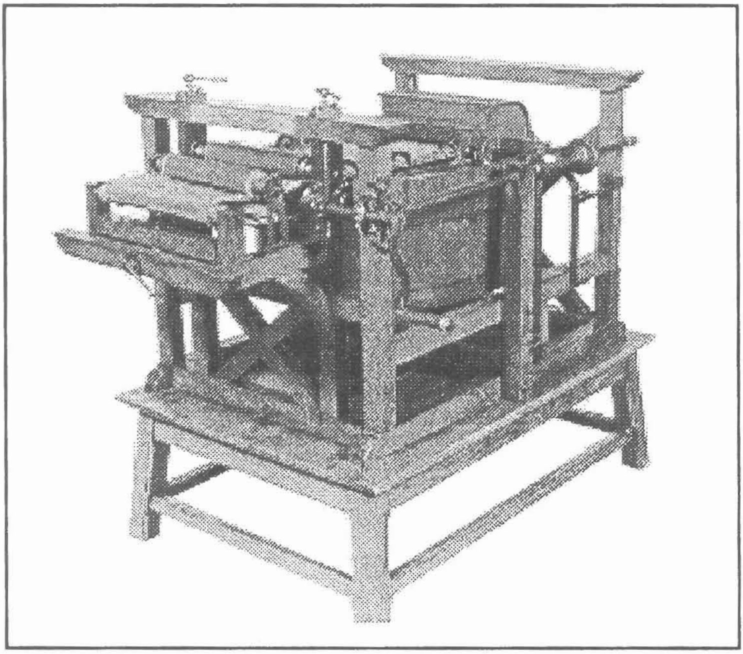

Figure 1 The 1799 paper machine by Louis-Nicholas Robert.

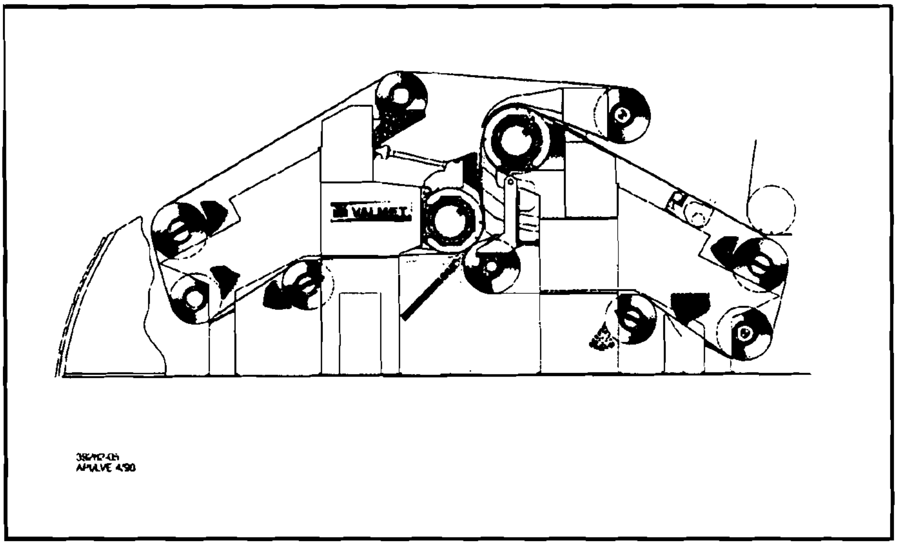

Figure 2 - The 1999 paper machine as conceived by Valmet (Optiformer™)

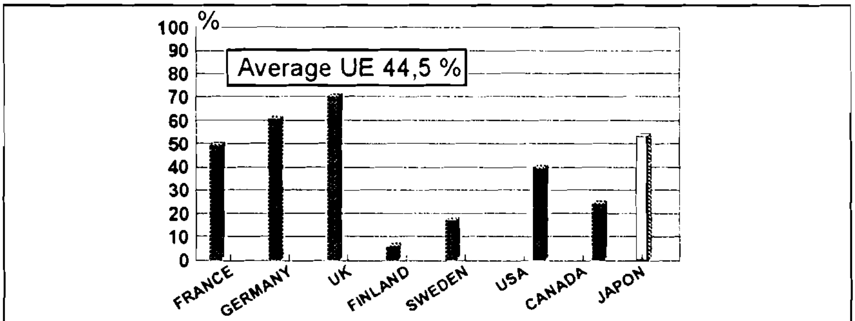

Figure 3: Wastepaper utilization rate (1996) in some paper producing countries

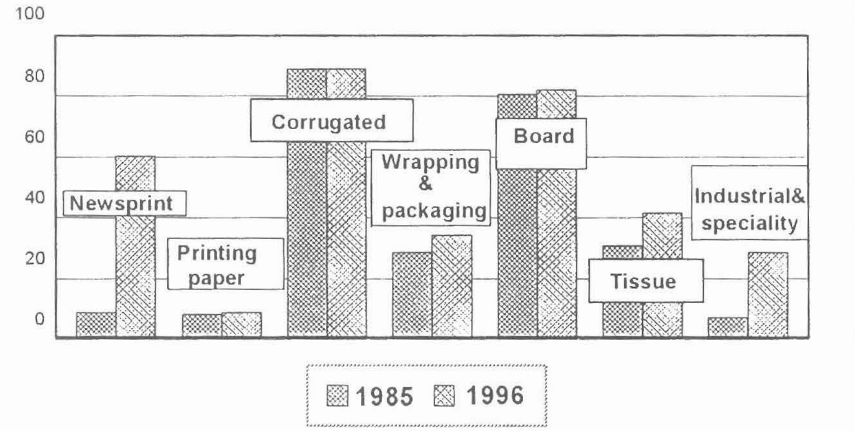

Figure 4: Wastepaper utilization rate for various grades of paper (France)

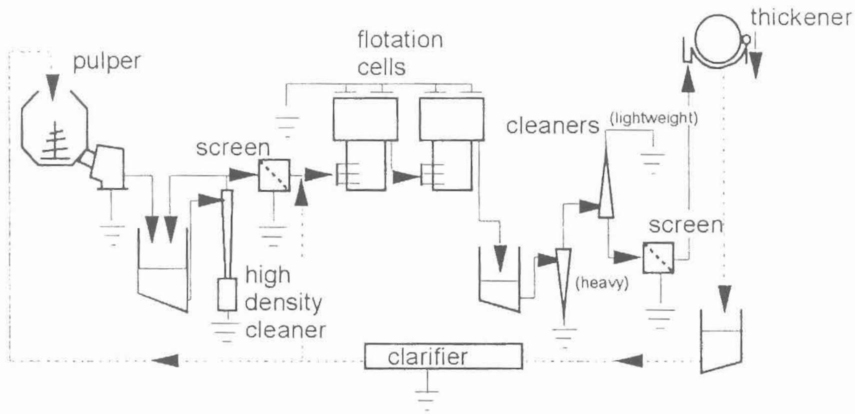

Figure 5: Basic flow-sheet diagram of a flotation deinking plant (production of DIP for newsprint from sorted wastepaper).

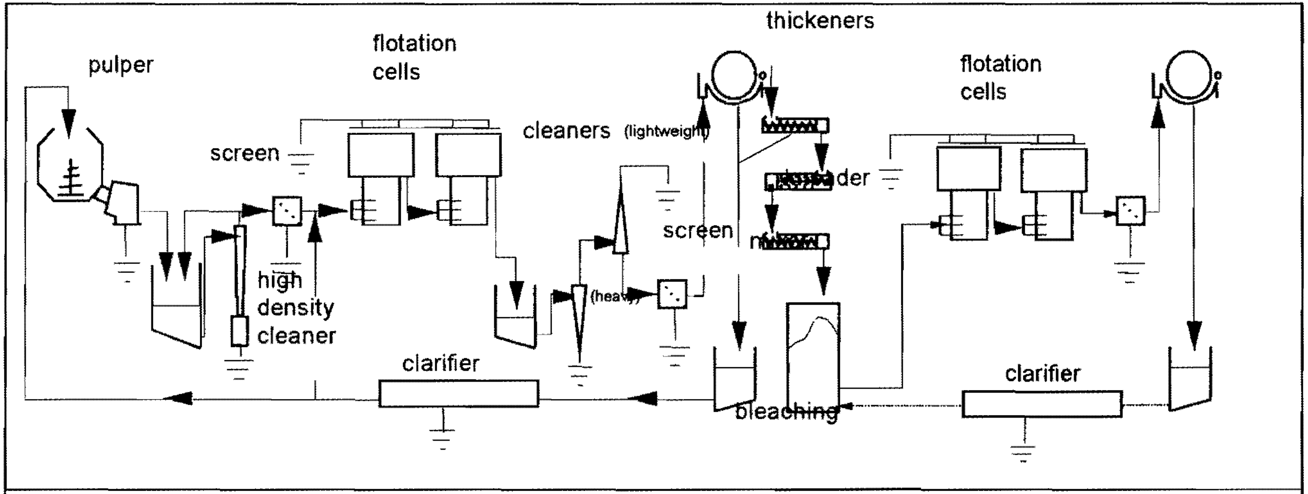

Figure 6: Multistage deinking process

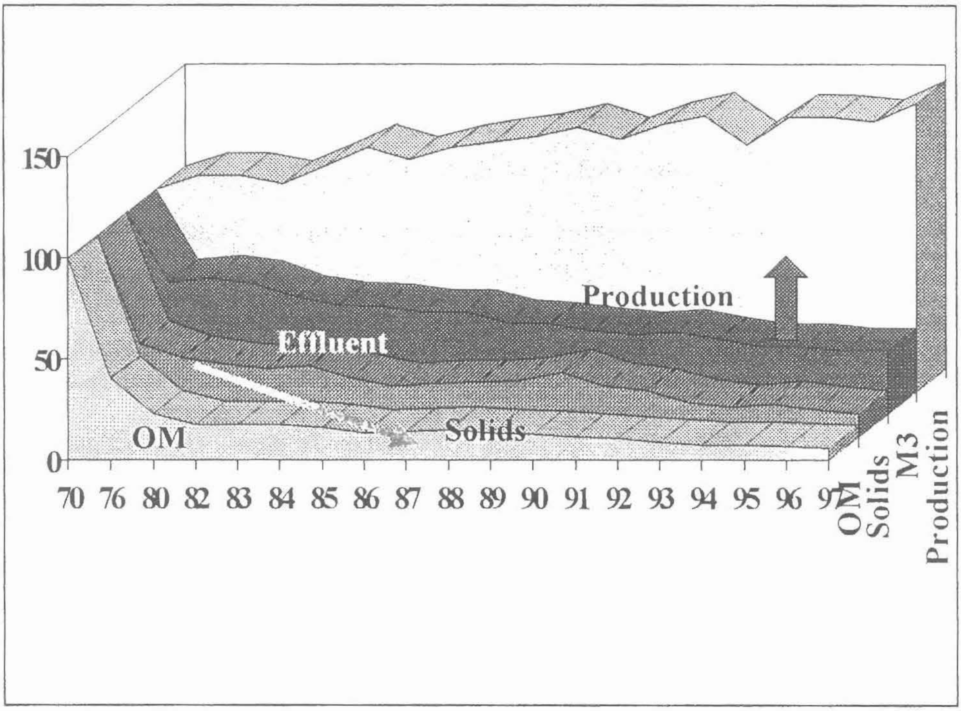

Figure 7 Reduction of environmental impact originating from the French pulp and paper industry. Similar graphs could be obtained from most countries.