Trends in Technological Developments in Pulp and Paper Industry

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Stagnancy in technological developments decelerates the growth of an industry, and conversely it is the dynamism in engineering and technology which helps it to grow. Now, there is hardly any field where paper and paper products do not find an application. This has been possible only through the tremendous developments in the technology of paper and paper products' manufacture.

The paper industry of today is facing serious challenges like—

(i) supply of paper and paper products to cope with the demand caused by population explosion;

(ii) the conventional pulpable raw material, though renewable, is becoming scarce due to increased harvest/replenishment ratio;

(iii) stringent restrictions on the discharge of effluents; and

(iv) the energy crisis.

Vigorous attempts are being made all over the world to find out solutions to these problems. Never previously in the history of paper industry has there been such a period of technological developments as we are at present experiencing. In fact, the technological developments taking place recently in the field of pulp and paper industry are so vast and divergent that a full discussion of these developments in an article like this will not be possible. We are, therefore confining our discussions to a few topics without touching:

(i) the explosion of new sheet forming methods;

(ii) innovations in wet press felt designs;

(iii) innovations as high consistency forming;

(iv) development of fully automatic Zeta potential instrument for continuous monitoring or fully automatic control in sludge treatment;

(v) on machine measurement of basis weight and moisture etc.

Developments in fibrous raw materials are mainly because of two reasons:

(1) firstly, many of the traditionally accepted fibers are becoming scarce day by day; and

(2) secondly, development of new materials with improved or different properties.

The global supply of softwood is limited whereas hardwoods are abundant. It has been estimated that within a few years time, almost all economically available softwood forest in the world, (except USSR) will be exploited assuming sustained yield. It is thus natural that in the future, the additional pulp and paper production will have to be based mainly on hardwoods. Over the past few years, there has actually been a gradual increase in the quantities of hardwoods utilized. Among the various alternatives that have been put forward to cope with the raw material shortage are :

(1) Better utilization of trees, like "whole tree utilization".

(2) Use of non-conventional pulps made from raw materials like begasse, reed, straw, kenaf etc.

(3) Development of pulping processes that economise in the consumption of pulp wood.

(4) Utilization of higher percentage of secondary fiber or recycled fiber.

(5) Development of non-cellulosic fibres. Though there will probably never be bulk replacements for cellulosic pulp by the synthetic ones, they have very specific properties that can be very useful in the design of technical papers.

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(6) Development of processes for the production of "test tube tress" is also on the anvil. This programme on forest genetics research is expected to produce reliable technique for the production of conifer tree hybrid, which might help to have wood based fibers of specific design. Some success in this line has been achieved by Weyerhaeuser Company[1]. Obviously the future success of parasexual manipulation and genome modification of forest trees depends upon the ability of researchers to optimise cloning procedures for different species.

The kraft pulping process is the dominant chemical pulping process all over the world; because at the moment no other process is available which produces pulp of equal strength at a comparable low cost. Since the invention of the kraft process around 1880, the chemistry of alkaline pulping and of its chemical recovery have not changed markedly, but the raw material base has been broadened significantly and also the equipment for pulping and chemical recovery has undergone a most impressive evolution. The Kraft process as presently used, has the following major process drawbacks.

(i) High raw material requirements per ton of product compared to the sulfite process.

(ii) It produces bad odour. Malodorous gases are created during the cooking and recovery of chemicals. These consist mainly of mercaptans, methyl Sulfides and H_2S. It produces polluants in the effluents. The major reason for the pollution is Na_2S. It causes toxicity to fish.

(iii) Kraft pulps are more difficult to bleach and require more bleaching stages and chemicals. Chlorine based bleached chemicals and up as chlorides in the bleach plant effluent and when the mill white water circuits are closed up, these chemicals lead to corrosion and overall mill efficiency problem.

Kraft pulping liquor dissolves hemicelluloses with a short chain length very early in the process. At the temperatures below 100°C the alkali also causes a weight loss of easily accessible hemicelluloses and some cellulose through the so called peeling reaction at the end of the chains. At higher temperatures, cellulose and hemicellulose chains are split and the so called secondary peeling reaction takes place at the newly created chain ends with further weight losses.

The degree of reduction of obnoxious gas-omission from kraft pulp mills is today basically a function of the number of collectors, fans and exhaust ducts.

New bleaching and bleachery washing techniques have been developed. The Papri Bleach System[2] is one such process developed by the Pulp and Paper Research Institute of Canada. Great Lake Paper Co., at Thunder Bay, Ontario pioneers a number of innovations, including one, the Rapson — Reeve[3] closed cycle system for getting rid of kraft mill water poullution. This is closed cycle system to wash the bleaching stages completely countercurrently and with so little water that the resulting volume is just enough to wash the brown stock. By this process, NaCl crystallizes out together with a small amount of Na_2CO_3 and Na_2SO_4. The crystals are removed from the evaporators which are reused as raw material for preparing fresh bleaching chemicals by electrolytic production of Cl_2 and NaOH and further transforming to ClO_2.

The classical Acid Calcium Sulfite process can be considered a dead process by reason of the impracticability of arranging for satisfactory recovery of chemicals. Progress in using other soluble bases, principally Mg, Na or NH_4 has been made. When Mg is used recovery is reported to be simple, but in practice, the upper limit of the pH range is about 5. Recently a new process with promising application to the Sulfite process has been successfully used in laboratory and pilot plant trials. This is the oxygen delignification of the magnesium pulp using $Mg(OH)_2$ as the alkaline buffer[2].

New pulping processes are primarily designed to give better untilization of existing resources without loss of the characteristics associated with the traditional pulps. If the present yields could be raised at the same kappa number, this would represent a considerable economy in resources. One such process is the polysulfide process patented by the Mead Corporation and running full scale at their Chillicothe mill since 1973. The advantage of polysulfide pulping is that it can hinder the so called peeling or attack of the end of the carbohydrate chain, thereby increase the final yield of pulp.

Another high yield chemical pulping process has been proposed and developed in Japan which is known as the sulfomethylation process[4]. In this process sodium sulfite and formaldehyde are used as the softening agents of coarse pulp and wood chips. They react to make Sodium-hydroxymethyl Sulfonate. In cooking the lignin which does not combine with carbohydrate is partly dissolved in the cooking solution while the lignin which combines with carbohydrate is converted to the hydrophilic and soft state by sulfomethylation and sulfonation. The resulting cooked chips may be easily defiberized mechanically without fiber shortening and specific fiber damage.

High yield H_2S pretreatment kraft pulping as proposed by Vinje and Worster[5] yields 12 to 14% more pulp than could be obtained by kraft pulping. In this process, the wood chips are given a pretreatment of H_2S prior to pulping by the kraft process. The process has been tried on a pilot plant with a capacity of about 14 tons per day at Macmillan Bloedel Ltd., Canada, yielding 14% more yield than conventional kraft and the printing quality of the paper is also excellent. The amount of sulfur consumed to obtain a yield increase of 5-6% based on wood is only 1.5% for this process compared to 4-5% by polysulfide pulping.

Semichemical pulping of hardwoods with kraft green liquor for corrugating medium is a recent development which is becoming increasingly more popular especially in integrated linerboard corrugating medium mills. The chemical preparation and recovery is very simple compared to NSSC pulping and the capital expenditure is also much lower[9]. Kimberly Clark Corporation, Wisconsin has proposed a new pulping process which is known as "Ammonia explosion process". In this process fiber separation is affected by means of an explosive decompression of wood chips which have been plasticized and chemically modified with Ammonia at elevated temperature and pressure. The product is composed of kinked, curled and twisted fibers and fiber bundles easily separated by mild mechanical action. The fibers have enhanced hydrating properties and retain their plasticity and flexibility in large degree even after removal of the ammonia.

North Carolina State University has developed most of the basics for the non-sulfur process called Oxygen Pulping process. The development of this two stage Oxygen pulping system seems to offer the most promising alternative to the existing kraft process in terms of yield and pulp quality. Its principle consists of Soda pulping to a relatively high kappa number followed by defiberization and subsequent further delignification with alkali and oxygen under pressure to the desired final kappa number. Pulp yield and quality are similar to those of equivalent kraft pulps except for easier bleaching, faster beating and lower tear.

Oxygen pulps produced by the one stage process developed by FPL, Madison, Wisconsin is superior to kraft pulp in both properties and yield. For balsam firs, Oxygen pulping produced pulps of 55-57% yield at a Kappa number of 6-12 whereas Kraft pulping produces pulps of 46% yield at a 24 Kappa number.

The use of Sodium Anthraquinone-2-Sulfonate as a polysaccharide stabilizer in alkaline pulping[6] and the anthraquinone and or its derivatives in improving the efficiency of alkaline pulping has been reported[7]. It has been shown that about 1% anthraquinone based on the weight of the o.d. wood yields pulp slightly higher and strength properties similar to those of kraft pulping. The activity of both anthraquinone and naphthaquinone is increased by the presence of electron donating groups e.g. 2—ethylanthraquinone[8].

Development of possibilities for efficient and economic utilization of lignin for various purposes has led to vigorous investigation of the solvent pulping using ethanol-water mixture. A solution of salicylic acid derivatives in ethylene glycol has been proposed as pulping agent[10].

From the stand point of pulp and paper manufacture there are currently available several new manufacturing methods for the production of mechanical pulp. It seems that the necessary qualifications for broadening of the raw material basis are in progress of development and that improved results will be obtainable in regard to energy utilization. It is now easier than ever before to produce mechanical pulp of a type which would be most appropriate for each of the applications concerned.

Probably no other major innovation in the pulp and paper industry has received the quick acceptance and immediate commercialization as has the process of TMP. TMP can be said to have received official blessings as a commercial process at the IMPC in Stockholm in 1973. At that time hardly any full size TMP plants were running. The IMPC at Sansfransisco in 1975 was again heavily dominated by TMP and the widely held attitude was that this process was going to be almost everyone's answer to every problem. However, the energy consumption of TMP is reported to be a great handicap for this process. It is reported that energy consumption in the case of TMP is about 50% higher than for stone ground wood. If TMP's high energy consumption and tendency to lint on offset could be licked it would perhaps eliminate all of the chemical pulp and most of the expensive pollution problems.

Most TMP is used for newsprint. It is also used for at least part of the furnish in several other types of paper and board and its importance as a pulp for printing and writing papers, coating base, multiplyboard, tissue and towelling is also increasing.

The annual capacity for TMP around the world at the end of 1976 amounted to about 2.5 million tons and is expected to go to 5.2 million tons by 1979. USA, Sweden and Canada account for more than 70% of the world capacity. Russia, Eastern Europe, South America, Africa and India do not have TMP mill whereas China has had one since 1975. The lack of interest for TMP mills for some countries is caution and for others it is the raw material. Soft wood works best with TMP. Some hard woods may be acceptable but mixed tropical hardwoods are the least suitable for TMP[11].

Another development in pulping is the Sodium Sulfite CTMP process[12]. This process involves treatment of shreded chips with Na_2SO_3 before RMP. For the production of pulps of equivalent freeness, specific refiner energy application required are in the order CTMP TMP CMP RMP.

A 30 tpd pilot plant is producing TCMP at the Price Co. in Kenogami, Quebec. It is used as a single pulp furnish for newsprint. Relative to RMP and compared at equal freeness the process gives pulps with substantially increased tear, reduced bulk and very much lower debris content. The process is reported to give softwood pulps with better wet and dry strengths than those of TMP pulps. 100% CTMP was compared with 3 other newsprint furnishes; 74% GWD+26% HYS; 88% RMP+12% HYS and 100% TMP. The CTMP furnish turned out to be the best in dry and wet strength as well as brightness.

The process essentially consists of shredding the wood chips in order to increase the surface area of the wood. The shredded wood is blown to a Cyclone, at the entrance of which the chemical solution is sprayed on. The temperature is raised to 100°C for about 45 minutes followed by refining.

The Pulp and Paper Research Institute of Canada examined Acid Sulfite pretreatment of wood. Acid Sulfite pretreated CMP and CTMP pulps were made in the 93% to 95% yield range and their properties compared to those corresponding RMP and TMP. Acid Sulfite was chosen for pretreatment mainly because it gives the highest rate of sulfonation of all sulfite liquors.

Another spectacular development claimed by the Norweigian Pulp and Paper Research Institute, is the improvement of the properties of mechanical pulp by treatment with Ozone[13]. The idea of using ozone to enhance the strength properties of mechanical pulp came about accidentally. It happened just when researchers at the Institute suffered a set back in their experiments with ozone. In the late 1960s they had been searching for a way to use ozone as a bleaching agent for mechanical pulp. They obtained good results in an acetone solution but when the pulp was transferred to a water solution brightness dropped to below the original level. After they accidentally found that ozone treatment remarkably increased pulp strength, they looked for some suitable reaction condition. It turned out that the reaction would work well in a water medium provided that the dry matter content of the pulp was between 30-50%.

It is reported[13] that hardwood pulp generally give better results than those from softwoods. TMP made from bisulfite treated chips responds specially well to ozone treatment. Ozone treatment of mechanical pulp from softwoods leads to a brightness reduction whereas the opposite is true for pulps from hardwoods.

Under guidance from Norweigian Pulp and Paper Research Institute, Holmen-Hellefos recently produced standard newsprint from a furnish of 70° SGW + 30% ozonized TMP. This paper was used to print an Oslo daily newspaper DOGBLADET at a normal press speed of 45000 copies per hour without any breaks. The usual 15% chemical Pulp component of the furnish had been replaced by 30% TMP treated with 2% ozone.

It has been concluded that ozone is a chemical agent with so many potential possibilities in the wood chemistry field that it is hard to find its counterpart. For the pulp and paper industry, ozone has been at the laboratory stage for over 60 years, but today it has moved on to the pilot plant stage and the next step forward is probably not too far distant!

Although there have been so many new processes developed for pulping, still the production of Pulp by the old and conventional processes are on the increase. Of course, because of the heavy investment involved in the adoption of these new developments, one cannot expect of everything changing overnight. There can, however, be no doubt about the pressure for rapid improvement in discharge to air and water. However, much more research will have to be undertaken with the long term objective of achieving sulfur free cooking and chlorine free bleaching. All evidence points to the success of this work being judged by how closely alternative processes can match the properties of the sulfate pulp, now being made by the traditional method.

Having seen the future demand for paper and paper products and at the same time expecting a shortage of virgin fiberous raw material, utilization of waste paper assumes greater significance and it has been felt all over the world that the gap between shortage and demand for paper and paper products can be bridged even partly by utilization of waste paper. Waste paper is, therefore, obviously going to play an increasingly important part in supplying fiber for paper and board making.

Until late forties, recycling of waste paper was fairly simple and straight forward recovery process. However, technological advances in adhesives, paper coating, printing inks, polymer cottings and other materials difficult to eliminate have created many problems in reusing waste paper today.

Although new deinking cells[15] have been designed and claimed to eliminate several disadvantages, the real solution to all the problems seems to be with the concept of waste paper drycleaning. In essence, dry cleaning uses organic solvents to remove waste paper contaminants, various mixture of Solvents are applied in tailor made situations. Still, the use of organic solvents to remove surface ink, varnish and other contaminants from printed paper is a new field with many more question than answers. Extensive research is needed to determine the best solvent mixture for each specific type of paper.

Similarly, as a consequence of the reduced availability of pulpable raw materials several industrial groups have been examining the possibility of developing synthetic fibrous products as a part replacements for cellulose. Composite papers of pulp and synthetic fibers have been shown to exhibit a wide range of characteristics with each synthetic fiber type possessing a unique set of assets and liabilities.

Replacement of Cellulosic fibers by synthetic fibers even to a small extent may not be possible because of the cost, particularly after the price hike in petrochemicals. Some speciality papers can, however, be made by taking advantage of the unique properties of the synthetic fibers. Addition of synthetic pulps imparts high degree of brightness and considerable opacity. A further advantage of the use of synthetic pulp in paper making is the possibility of obtaining paper with a lower basis weight at equal thickness.

Bleaching is currently the least economic and most polluting operation in the whole pulp manufacturing process. The present trend in bleaching is to develop processes where the consumption of water is minimized. This calls for rearrangement in washing process either so that washing efficiency is higher than it is today or so that no real washing is necessary at all. The bleaching chemicals must be recovered and the matter dissolved during the bleaching disposed of.

The Oxygen/alkali bleaching offers a possibility of recovery and disposal of the organic matter. The main objective of oxygen bleaching and the closed pulp mill concept are to significantly reduce or eliminate water pollution from a bleached pulp mill. Oxygen bleaching has been proven in commercial operation and will find wide application in future. The present trend also aims at development of bleaching methods to save as much lignin as possible in order to get higher pulp yield. This is possible by irreversibly blocking the chromophoric groups in lignin. Opportunities for effective control of the bleaching process are now on the increase. Determination and regulation of the amount of active clorine by continuously working optical tester are bringing the bleaching process towards computer control. With the aid of computer control the consumption of chemicals may be reduced and quality variation decreased.

Restrictions of the nature and amount of polluants, which can be discharged from pulping operations are becoming more stringents not only in the developed countries but also in developing nations. This means more pressure on pulp mill management and Engineering and Technical staff to selelect design and install new factories which can meet the official requirements. This threatens the profitability of pulp and paper industries of all countries including developing countries striving for sufficiency in this essential commodity. Many mill in America had to be closed down because measures required to reduce pollution were much too costly. Japan is one of the first few of the major producers of pulp and paper to take up a comprehensive scheme to reduce pollution and develop new technology and equipment to make the treatment more economic and easily adoptable.

If air and water are first two pollutions, noise is the third. And although noise regulations are not yet as numerous as those governing the first two, the pulp and paper industry is busy finding solutions to this problems also.

Studies on the development of newer products from cellulose and paper are there almost all over the world. Particular reference may be made to the development of (i) various types of cellulose derivatives which can be tailor made to become suitable for any subsequent end use, (ii) grafting of cellulose with other polymers for special use.

It is exciting to know that novel cellulose derivatives which have speciality of structure and end uses can be made on a commercial scale. Rayon fibers are available whose properties can be tailored by grafting. Particular reference may be made of the work done in USSR which has produced hemostatic gauge and ion-exchange fibers and fire retardancy can also be built into the fabric. As these new fibre and film technologies enter the market place it is safe to project that they will produce new application at an accelerating pace.

Thiocarbonation redox grafting pioneered by Brickman et al[14] is a new method developed for tailor making new cellulosic products of specific and uses without losing the important attributes of the cellulose substrate. This method does not require the high purity reagents, special atmosphere or other somewhat exotic condition usually specified for grafting system.

Spectacular developments in the field of pulp and paper technology are taking place at an accelrating pace based on the trends of R & D efforts all the world over. The technology for pulp cooking, washing, bleaching etc. is bound to change rapidly. There has been an explosion of sheet forming devices and new and sophisticated products have been developed from paper and cellulose derivatives. Future mills will be practically effluent free and use less energy than mills today.

One of the major social and economic problem facing the world today is the imbalance in the distribution of technology and its adoptation Energy, environmental protection and resource recovery, to name only a few of the challenges that we are facing today, are not confined to a particular country or region. To combat these challenges, we require not only the best technologies available today, but massive research and development effort that might result in new technological breakthrough.

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