Some Thoughts On Increasing Productivity

PANDYA, V.H.*

The potential of increasing productivity is our best hope for coping with inflation and competition The true measure of efficiency is total factor productivity, which is computed by dividing output by a figure that represents all of the resources uses in achieving the output, including capital, labor, and land. However, because of the difficulty of computing the number used as the divisor, a similer approach is usually employed, such as computing and comparing partial productivity rather than total factor productivity. Frequently, the latter consists of the ratio of physical output to a single input such as labor. Thus, in many discussions, productivity means labor productivity or output per man-hour of work. In fact, it is often stated that this is a rough measure of the effectiveness with which we use labor-our most important resource. However, this paper deals with a number of potential increases in partial productivity of pulp and paper mills that are largely independent of labor, increase output per man-hour of labor.

PULPING

Mechanical, Chemimechanical, Semichemical, and Chemical Pulps

Higher and higher wood costs require more and more complete utilization of wood and other sources of fibres, such as bagasse. The increased use of pulp described as chemimechanical points the way to much more complete wood utilization. This can be expanded markedly past the overall achievements to date by a greater use of paper and paperboard prepared from chemimechanical pulp as merely a structural member. Viewed in this perspective, a surface of any desired character or color can be provided by the application of a suitable coating to a base stock composed of more than a start has been made on the overall potential increase in partial productivity that can be realized from such an approach.

Although the wood utilization achieved in chemical pulping processes does not approach the 85 to 95 percent yield for chemimechanical pulp there are also ways in which increases in yield of chemical pulp can be attained. There are two or three performance proved pulping aids available e.g. Anthraquinote and amides of fatty acids – that will provide increases of yield of 1.5. to 2.5 percent when proper adjustments are made in the cooking liquor composition, cooking time and/or cooking temperature to take full advantage of the benefits that the pulping aid provides. An increase in yield of this magnitude is difficult to measure in many pulp mills. However, increases in yield of the indicated amount have been reported from many mills using semichemical, sulfite and kraft processes. It thus is believed that the time has come when an increasing number of mills should move forward and take advantage of currently available pulping aids. New pulping aids to come most assuredly can and will make a contribution to increased productivity in the pulping of wood and potentially in the pulping of other sources of fiber. The overall magnitude of this increase in productivity will depend upon the degree to which the pulp industry opens its mind and recognizes that there are benefits to be obtained from the use of a properly functional pulping aid. Prior unsucessful attempts with what were intensively promoted, but ineffective products should not be allowed to inhibit forever the broad use of pulping aids that do provide substantial benefits above their cost.

Recycled Fiber

There are substantial potentials for increased productivity, conservation of natural resources, and reduction in pollution by the recycling of much larger amounts of fiber. Modifications of old processes and the availability of new chemical products make it possi-

*Tachnical Partner Chemofarbe Industries

ble to handle more difficult repulping and deinking problems. The new processes and equipment in general provide more intensive mechanical action in the repulping process. This in itself enables reusing more difficult-to-repulp broke and waste paper and paperboard. Moreover, when the more effective repulping equipment is combined with newer chemical repulping aids, there is an even greater potential for recycling much larger amounts of fiber. The newer chemical repulping aids take the from of more effective penetrants, dispersants, and solvents, as well as combinations of such components, which are applied in solving the more difficult repulping problems. In addition, the newer chemical repulping aids are frequently employed along with conventional acids, alkalies, and oxidizing agents such as calcium hypochlorite, with the last being used particularly in the repulping of wet-strength broke and recycled paper and paperboard products manufactured with polymide resins. In fact, there now is a greatly expanded potential for recycling paper and paperboard and the utilization of the recovered fiber in more and exacting paper products. The savings in fiber costs obtained in this way make it an attractive potential for increasing productivity.

PAPER AND PAPERBOARD MAKING

1. Forming.

Retention, drainage, formation, and strength are inter-related factors in the manufacture of paper and paperboard In turn, the combined effect of changes in one or more of these variables can have an important bearing on the speed at which paper and paperboard can be produced on fourdrinier and cylinder machines. It thus is important to make a coordinated review of retention, drainage, formation, and strength in any overall consideration of ways to increase productivity.

Retention

It is properly the desire of paper mill personnel to retain a maximum amount of the total furnish to the machine in the paper and paperboard produced and to sell it as finished product. In the past, this desire has been related paimarily to the retention of high-cost pigments, such as titanium dioxide, and, to a lesser extent, to the retention of fines to achieve desirable sheet properties. In many countries, there now are or soon will be forceful added reasons to increase retention because of the more stringent regulations on the quality of the water that is discharged from the mill.

There are three general mechanisms of retention that are currently recognized[5]. One is described as sieving, i. e. the process of retaining particles larger than the pore opening present during sheet formation by filtration action. The second is the entrapment of particles in the fibril structure on the fiber surface or in the fiber lumens. The third is the mechanism described as coflocculation, which consists of the interaction of the two general types of interfacial forces that control colloidal flocculation. These relate first to the collapse or compression of the electric double layers on colloidal, particles and the influence of such action on the stability of the particles, and, second, they relate to the development of polymer bridges between particles. In the latter case, a portion of a polymer attaches itself to one particle by electrostatic or physical bonds, and the remaining portion becomes attached to another particle. Both of these actions (i. e. the changes in the electric double layer on the particle and the bridging between particles by polymers) can occur simultaneously to varying degrees. The first mechanism is described as coagulation and the second as flocculation, with the term coflocculation being applied to the combination of the two, which is regarded as the dominant mechanism whereby pigments, fillers, and fine fibers are retained in the sheet during the papermaking process.

Fortunately, there are a number of products available that will help increase retenting of pigments, fillers, and fine fiibers during the manufacture of paper and paperboard. In addition, many research staffs are at work on the creation of new and better products for the paper industry to use in increasing retention. Currently, the most commonly employed types are :

1. Inorganic chemicals, such as alum, clacium chloride, and sodium silicates.
2. Natural organic polymers, such as gums and starches, proteins, rosin acids, and salts thereof.
3. Modified natural organic polymers, such as cationic and anionic starches

4. Synthetic organic polymers, such as the polyacrylamides, acrylamide copolymers, polyethylenimines, and new types of polyquaternary ammonium compounds.

5. Combination inorganic and organic retention and drainage aids, which may also serve as deaerators.

The natural and synthetic polyelectrolytes are the most extensively used polymeric retention aids. Their performance is influenced by the characteristics of the polymer molecules and the environment in which they must function. Some of the quite generally recognized key characteristics influencing the degree of performance of polyelectrolytes are:

1. Molecular weight
2. Electrical charge and density of the charge
3. Functional groups
4. Spacing of the functional groups
5. Chemical and physical environment, such as pH, concentrations of pro and counterions, shear stresses, and amount of entrained air in the paper furnish.

In the pulp and paper industry, molecular weight of the polymer may still receive more attention than this one characteristic alone justifies. Unquestionably it is important, but it does not necessarily follow that the retention aid with higher molecular weight is the best one to use. Even when it provides the highest retention, there may be a sufficient adverse influence on formation to rule against employing it. The need to select a polyelectrolyte with properly balanced properties is becoming much more broadly recognized than it was several years ago. There also is increasing appreciation of the importance of the chemical and physical environment on the functioning of any given polyelectrolyte as a retention and/or drainage, formation, and strength aid.

Williams[5] has presented a good review of some of the practical interrelationships involved in achieving optimum retention in paper and paperboard making in the light of current knowledge about the behaviour of colloids. It he used to illustrate the charged surface of a colloidal particle, the counterion layer, and the potential energies of interaction between particles. When a solid is placed in contact with water, a charge develops at the surface as the result of the ionization of surface groups or the result of the ionization of surface groups or the specific adsorption of ions. The charge on the solid particle usually is negative. As shown, counterions also are present, and the system as a whole is electrically neutral. The balance between the electrostatic repelling forces and the forces of attraction determine whether or not the particles will remain dispersed or will coagulate when two particles collide. Obviously, the stability of the system can be altered by changing the pH or the ionic environment in which the particle is in suspension.

According to the well-known Schulze-Hardy rule, the effectiveness of a counterion in overcoming repulsion and achieving coagulation is proportional to the inverse sixth power of its valaence. This, of course, explains the much higher effectiveness of alum than that of a monovalent cation in coagulating negatively charged colloidal particles. As Williams[5] discussed, alum can bring about diffuse layer compression as well as charge reduction on a negatively charged colloid, such as paper making fibers and clay in water. When this knowledge is combined with the prevalent use of alum in papermaking and the recognition of the interference with the action of alum by complexing negative ions such as sulfate, one starts to see the complexity of the interactions that influence retention in the papermaking process. Obviously, we add new factors and increased complexity when we introduce a polyelectrolyte capable establishing polymar bridges between fiber, filler, and pigment particles. The polymer will make a contribution to the degree that the environment favours adsorption and the shearing forces are kept within satisfactory bounds, To achieve the desired objective of increased retention, proper chemical and other balances must be maintained in process water, pulp, broke, alum and other additives. Usually this involves a generous portion of practical considerations along with the theoretical ones briefly menttoned in this paper. However, there is a reward in the form of increased retention and, in turn, increased productivity for those with the patience necessary to gradually work toward the best combination of conditions to produce optimum retention.

Drainage

Like retention, drainage is also influenced by a number of different factors, and one of the authors has discussed some of the more important ones in a previous paper[4]. That discussion categorized the relevent factors as drainage driving forces and drainage resistance forces. The drainage driving forces mentioned were :

1. Hydrostatic pressure from the weight of the stock on the wire

2. Inertial pressure from the angular impingement of the stock jet from the slice on to the wire

3. Hydrodynamic vacuum forces generated by the motion of the wire over the table rolls or drainage foils

4. Externally generated vacuum forces applied by means of suction boxes under the wire

5. Pressure from rolls, such as dandy rolls,

In contrast, the following were listed as drainage resistance factors :

1. Temperature – Raising the temperature reduces the viscosity of the water and increases the drainage rate.

2. Degree af refining – Generally a more highly refined stock drains more slowly than a less refined one.

3. Nature of the finer surface – Different pulping processes produee fibers with different surface characteristies, which in turn, results in different drainage characteristics.

4. Flocculation – Increased flocculation usually forms larger pores in the sheet, which results in a higher rate of drainage.

5. Presence of electrolytes $\frac{3}{4}$ reduction of the magnitute of the charge on the finer surfaces by electrolytes reduces the thickness for the layer of bound water on the surface of the fibers and thereby, in effect, increases the size of the pores, which in turn, increases drainage. There also may be some increase in pore size by virtue of an increase in flocculation caused by the electrolytes, as noted under No. 4.

6. Presence of surfactants – Reduction in surface tension by different types of surfactants and reduction in the thickness of the bond water layer on the surface of fibers by cationic surfactants will both increase drainage.

7. Air in the stock—the results reported by Brecht and Kirchner[2] on the effect of air in papermaking stock. As indicated, they found that even relatively small amounts of air caused quite large increases in drainage times In addition, increasing amounts of air adversely influenced strength properties and smoothness of the paper.

A program of improving drainage, of course, can be directed at increasing any of the drainage driving forces and/or decreasing one or more of the drainage resistance factors. A saving can result from removing a larger proportion of water by drainage on the wire or the cylinder mold in contrast to removing it in the press section or by the much more costly vaporization process in the dryers. Moreover, this can frequently be accomplished by the use of a chemical deaerator without any significantly increased capital expenditures. In addition improved formation is frequently observed supplementary benefit. For some types of paper, this benefit alone has been regarded as more than justifying the cost of the chemical deaerator that was employed Even when such is not the case, the total gain in partial productivity usually is enough to be quite rewarding. The fact that it can be evaluated without a significant capital investment and with only a nominal expenditure should encourage a quite broad evaluation of this say of achieving an increase in productivity.

Formation

As indicated under "Drainage", there is a complex interrelationship between the removal of water by drainage and the formation of a sheet of paper or paperboard. The size and surface characteristics of the fibers, the kind and amount of filler and pigments, pH, Ionic enviornment, and amount of air in the stock all have a bearing on formation as well as drainage. The nature of the machanical devices used in removing water also have an influence on formation as now become quite generally recognized. A good illustration of this is provided by the decreased loss of fines and the more even distribution of fines he through the sheet when foils are used in place of table rolls. The nature of the graduated flatbox vacuums also has a bearing on the amount of fines retention and degree of two sidedness. There thus are mechanical as well as chemical approaches to drainage and formation improvement. As previously indicated, however, the latter merit attention first because the magnitude of their benefit can be determined without the necessity of a significant capital investment.

Strength

When one reaches beyond those things done with natural fibers and natural bonding materials, such as starches and gums, there obviously is too extensive a subject to cover in this paper. There already are a number of synthetic wet end adhesives or bonding agents to enhance both dry and wet strength, and many more are certain to come. This is as it should be. Such work will make a contribution to the versatility of paper and paperboard so that these products will better meet old as well as new needs.

In summary of the portion of this paper that briefly covers retention, drainage, formation and strength, one should stress again the interrelationships involved among these four properties. To achieve maximum success, any program of work should take this fact in to consideration. In the face of it and the availability of a large number of products that may influence one or may influence one or more of the indicated four properties, one might properly ask, "What should I do first?" With the recognition that there is an abundant opportunity for a difference of opinion, the following are suggested as the first steps to take to increase productivity :

1. Reduce the air content of the stock to a minimum by the use of a chemical deaerator that will not significantly decrease the surface tension of water.
2. Fully develop the optimum retention, drainage, formation, and strength that can be achieved from the use of a polyelectrolye or a natural polymer such as starch that has been cationized in the mill.
3. Maximize water reuse and control deposits by the use of a dispersant with defoaming properties along with a broad-sprectrum microbicide.

Enough increase in productivity will usually be achieved from the three steps indicated to encourage a continuing program of work that will result in surprising total benefits. Moreover, such benefits can be achieved gradually by the process known as evolutionaly operation[1,3] without any significant risk of producing a nonspecification product. This approach, combined with that of applying incremental costs in evaluating the results achieved[6], will provide a more accurate picture of what is being accomplished. As Wills[6] indicated, when one ton per day is added to the output of a paper machine, there is normally no change in labor, supervision, or otherhead costs. Although the costs of materials, steam, electricity, and maintenance do change, the increment cost per ton of increased production is less than the cost per ton of the existing production because only some of the costs are increased. As an example in a fictitious typical situation, it was computed that it cost US $ 105.50 per ton to manufacture and sell 500 tons of unbleached kraft linerboard perday. In contrast, it would cost only US $ 68.95 per ton to manufacture and sell an increment of 50 additional tons per day. The markedly increased amount of profit per ton for the added increment of production is well worth the corporation effort to achieve.

11. Pressing

The sheet entering the press can contain 80 to 85 percent water, even though there has been a maximum endeavour to remove water in the wire section. Obviously, the lowest cost way to remove water is to drain it from the sheet. However, there still is a major advantage to removing a maximum in the presses compared to the cost of evaporation in dryers, which costs roughly 10 to 15 times as much. This differential gave rise a number of years ago to the use of suction presses of progressively improving design. The variables that influence the water removal at the press can be summarized as follows :-

1. Off couch moisture
2. N p pressure
3. Speed
4. Roll parameters, such as rubber hardness and diameter
5. Felt quality
6. Felt porosity
7. Felt age

It is outside the scope of this paper to provide a detailed discussion of all of the factors influencing the amoutnt of water removal in the press section. However, as noted, three important factors influencing amount as well as uniformity of moisture removal are felt quality, felt porosity, and felt age. Continuous chemical conditioning treatments have demonstrated their effectiveness in maintaining increased overall Felt performace and better uniformity of moisture removal accross the width of the sheet throughout the life of the felt. Felt plugging can be determined by porosity measurements, and the results of such measurements have often been the motivating force that resulted in the initiation of continuous felt treatment. However, the merit of such treatments can usually be demonstreated quite easily by the application of a suitable continuous treatment over the life of several felts. Inhibited acid treatments are now available that do not introduce chlorides into the system or involve expensive acids, such as sulfamic.

III Drying

Dry is by far the most expensive way of removing water from paper or paperboards. As previously indicated, it costs roughly 10 to 15 times as much to evaporate water from paper and paperboard as it does to remove it in the press section. Moreover, it is less expensive to remove water by drainage than it is by pressing. It obviously follows that the most efficient way to reduce the cost of drying is to increase the amount of water removed by drainage and pressing. Whatever can be accomplished in this way also has the possibility of being translated into increased production if the drying section was the limiting factor in terms of tons of paper and paperboard that could be manuf ctured. If it was, we should remember the low r cost and higher profit to overall productivity.

IV. Costing

A reference to costing and other surface treatments is included in this paper because coating in still another way to increase productivity. Chemimechanical pulp produced in 85 to 95 percent yield is being used successfully as coating base stock. It is recognized that good formation; freedom from holes, lumps, and shives; and adequate strength are all desirable properties to provide the best surface for coating. However, coating is way to utilize high-yield pulp and still provide the user with a suitable surface to meet many different needs. Moreover, the very large growth in the use of coated paper and paperboard attests to the progressively increasing degree of customer satisfation that coated paper products are achieving. Clearly, such products are part of the answer to a more complete utilization of our natural resources, as well as the provision of products with surfaces that meet the progressively more exacting needs of users of paper and paperboard.

EFFLUENT

Even after considerable thought, effluent problems may seem to be much more of a liability than an asset. In many cases, this may prove to be the situation for a relatively long time to come. However, solving effluent problems can often give rise to worthwhile savings in terms of fiber, pigments, filler, size, alum, heat and water. We must make the most of such savings if for no reason other than the help they will be in reducing the cost of overall pollution control. Progressively more exacting requirements for the control of air and water pollution are with us to stay. Everyone must together to meet them in the most efficient way. As we do, the indicated benefits can and will make a contribution to increased productivity.

SUMMARY

There are a number of ways to increase productivity in the pulp and paper industry. Most mills have programs of work in Progress in an endeavour to improve their efficiency. However, it seems worthiwhle to briefly review some of the more important opportunities with the hope that such a review would encourage additional work on one or more of the following :—

1. Increase yield of useful fiber and improve kraft liquor-recovery applications by using a pulping aid and making appropriate adjustments in the cooking liquor and/or cooking conditions.
2. Use increased amounts of lower cost re-cycled fiber by taking advantage of new repulping and deinking aids and/or more effective repulping equipment.
3. Improve retention, drainage, formation, and strength by the use of a chemical deaerator alone or in combination with a polyelectrolyte.
4. Maximize water reuse in all phases of pulp and paper mill operations to minimize effluent problems and conserve fiber, pigments, filler, size, alum and heat with the help of a foam-inhibiting, dispersant and a broad-spectrum microbicide.
5. Increase the amount and uniformity of water removal in tbe press section by continuous conditioning of wet felts.

Experience in a large number of mills throughout the world supports the conclusion that very worthwhile increases in productivity can be achieved by well-planned and carefully executed programs based on the principles reviewed in this paper.

LITERATURE CITED

1. Box G.E.P.
   1957. Evolutionary operation : a method for increasing industrial productivity. Applied statistics VI (2) : 81–101
2. Brecht, W., and Kirchner, U.
   1961. The air content of pulp suspensions (German). Das Papier 15 (10A) : 625–634.
3. Koehler, T.L.
   1959. Evolutionary operation : Its method and application. Tappi 42 (3) :261–264.
4. May, O.W.
   1967. Increasing production of paper machines. I. Improving drainge on fourdrinier wires and cylinder molds. Southern Pulp andPaper Manufacturer 30 (9) : 72, 76–78 80–81.
5. Williams, D.G.
   1973. Minimizing chemical and fines buildup in white water by chemical means. Paper presented at 1973 TAPPT Annual Meeting, Chicago, 111, USA., March 5-7, 1973.
6. Wills, C.L.
   1971. Applying increment costs in evaluat ing projects. Tappi 54 (2): 212–214.