Continuous Pulping and its Place in Indian Pulp Industry

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Abstract: Salient features of various equipment employed in different continuous cooking systems are described. Advantages of continuous cooking in contrast to batch cooking are outlined. Reasons for delayed and limited application of continuous pulping in India have been put forward and emphasis has been laid on a wider application of this novel technique in Indian Pulp Industry.

1. Introduction: The impact of innovations in the field of pulping has brought about a revolution in the processing techniques of ligno-cellulosic materials during the last two decades. Development of continuous pulping on sound footing is one of the commendable achievements of the recent past of this industry. It is only recently, by incorporating this novel technique that all the operations of a pulp mill, starting from raw material preparation to baling of its finished product, could be streamlined and the big hurdle placed by the batch digesters in the path of achieving this long awaited objective could be crossed successfully.

The first continuous digester was commercially employed in 1944 for the manufacture of corrugated grade pulp (1). During the last twenty years or so, a major portion of which represents its development stage, this technique has been so rapidly and widely adopted by the industry that at present it meets around 20-25% of the world total pulp requirement; and plants capable of producing as much as 900 tonnes of pulp per day are under installation.

2. Continuous Cooking Systems: A typical continuous cooking system essentially consists of the following main pieces of equipment:

A. Pretreatment Equipment:—To presteam and/or impregnate with the cooking liquor a suitably prepared fibrous raw material.

B. Feeding Device:—To feed the pretreated material into the continuous digestor under pressure.

C. Continuous Digestor:—To cook the material to the desired degree.

D. Discharging Mechanism:—To discharge cooked material from the digester.

2 A. *Pretreatment Equipment*:—The function of this equipment is either to make the fibrous material capable of taking cooking liquor quickly and uniformly or to carry out penetration of the cooking liquor into the material. The choice of the prices and the design of the equipment for pretreatment depends not only on the type of the fibrous material it is to handle and the quality of pulp it is to produce but also on the cooking system. For agricultural fibres Pandia system uses a twin paddle mixer, Escher Wyss—an impregnating screw, Celdecor-Kamyr—pre-impregnator followed by a low pressure impregnator, etc. For wood chips or similar materials, Escher Wyss system uses an evacuation chamber with a following penetration vessel, Pandia—screw conveyor, Defibrator-Prox pressure expansion technique after presteaming and Kamyr system simply presteaming.

2 B. *Feeding Device*:—The most important piece of equipment in a continuous pulping system is the device which feeds the material into the digester against cooking pressure. Feeders of plunger type, screw type or rotary valve type have been employed for this purpose. Plunger type feeders are obsolete now because of their disqualifications like intermittent feeding and unsteady power load. Screw

feeders generally find their application for feeding the bulky materials like straws and bagasse. Rotary valve type of feeders are most widely used for this purpose and the trend is for their still wider application because of the distinct advantages, as given below, they offer over screw feeders.

(i) Complete elimination of the possibility of backblows from the continuous digester.

(ii) Low power requirement. It requires as low as one-eighth to one-tenth of the power required by a screw feeder for the same feeding rate.

(iii) No detrimental effect on pulp quality because the material is transferred from low pressure region to high pressure region without causing any mechanical injury to the fibres.

(iv) Simple to operate, smooth to run and easy to maintain.

The only slight disadvantage of a rotary feeder over the other two types of feeders is that each pocket of the feeder when feeds the material to the digester, it takes out from the digester high pressure steam which finds its use for the purposes where low pressure steam would have otherwise been employed.

Rotary Valve Feeders: A rotary feeder is a precision built valve which consists of rotor having pockets revolving slowly in a close fitted housing. As the rotor turns the pretreated fibrous material falls by gravity into the rotor pockets (some designs use means like steam nozzles for feeding the pockets) which are emptied when they reach over the digester opening for the intake of the material. The steam is relieved from the empty pockets through the blow off opening in the housing.

Design of a satisfactory feeder poses so many problems because it has to undergo severe thermo-mechanical stresses caused by expansion and contraction due to changes in temperature and due to deflection caused by pressure differential on its rotating plug and at the same time maintenance of just required clearance between the rotating plug and its casing to seal the pressure effectively. Rotary feeders of a variety of designs are commercially in use. Some feeders use cylindrical rotors while others use conical. Some rotors have spherical pockets while others more or less trapezoidal. Certain designs entail use of high pressure steam to facilitate emptying of pockets while in others pockets are emptied by gravity. In some designs pockets are emptied by flushing them with the cooking liquor. Number of pockets in a rotor varies with the design of the feeder and the fibrous material it is required to handle. For feeding agricultural residues the number of pockets is much less, of course, pocket size is bigger than those meant for feeding materials like wood or bamboo chips. Rotors having two to eight pockets are quite common.

Screw Feeders : Basically a screw feeder is nothing but a specially designed tapering diameter screw which forces the fibrous material into a plug pipe where it gets sufficiently compressed and forms a steam-tight plug to seal the pressure of the digester. The key point in the successful operation of a screw feeding device is that it should be capable of forming a solid plug of fibrous material without damaging it and the plug should be adequately compressed all across its cross-section. In general screw feeders are known to have a detrimental effect on pulp quality because they cause some mechanical injury to the fibres while forcing them to form a plug. Extent of their detrimental effect largely depends on the nature and the state of the material to be fed and the design of the screw. Softwoods are known to be the most prone to damage by screw feeding. It has been pointed out (3) that by designing the lead of the screw and the taper on the outside and the root diameter suitably, a uniform compression of chips in all directions with minimum chip to chip motion can be achieved and thereby damage to fibre can be brought down to a bare minimum. But how far this condition is practically met is a doubtful point. Moreover, a design of a screw feeder may be ideal for one raw material, it is not always necessary that it will be equally efficient for other raw materials as well. In some designs the possibility of back-blows with a screw feeder has largely been eliminated by extending the root of the screw through the plug pipe and thereby sealing the core of the fibrous plug for back-blows.

To sum up, for feeding materials like bamboo or wood chips the use of a rotary valve should be preferable to a screw feeder, but for feeding bulky materials like bagasse and straws different cooking systems should be carefully studied for individual requirement. To manufacture fully chemical pulps from these materials the use of a screw feeder preceded by a suitable impregnating equipment may be preferred to a screw feeder. The use of a screw feeder for operations like low pressure impregnation can normally be considered quite satisfactory.

2 C. *Digesters*:—Continuous digesters can be classed into the following four general groups:—

(i) Horizontal Tube Type: such as Pandia Grenco and Defibrator

(ii) Inclined Tube Type: Such as Bauer M & D.

(iii) Vertical Downflow Type: Such as Kamyr, Escher Wyss, Defibrator and Celdecor Pomilio.

(iv) Vertical Downflow Type: Such as Impco.

(i) *Horizontal Tube Type Digesters*:—These consist of one or more horizontal tubes connected in series. A screw conveyor for each tube is used for the movement of the fibrous material. Each tube may have its separate liquor circulation and fortification system. Thus cooking liquors of different composition and/or concentration can be used according to the requirement in different tubes. Also, by providing feeders in between the tubes, cooking pressure sand temperatures can be controlled as desired. Systems of this type ensure uniform cooking because of uniform flow or fibrous material in the tubes with no possibility of channelling in them. But there is every possibility of slight mechanical damage to the fibres by the conveyors, though they rotate at a very low speed, especially when dealing with fully chemical pulps.

(ii) *Inclined Tube Type*:—Digesters of this type also have one or more tubes but these are installed in an inclined position instead of horizontal. In the Bauer M & D system these tubes are put at an inclination of 45°, and each of them is divided into two sections formed by a midfeather along their axes. Each tube is equipped with an endless conveyor for the transportation of fibrous material into them. The main advantage of an inclined tube system over a horizontal tube system is that submerged or partially submerged cooking can be carried out with them, whereas, a horizontal tube system does not have such a flexibility.

(iii) *Vertical Downflow Type*:—Systems based on this design have a vertical pressure vessel slightly tapered out downwards in order to ensure uniform downflow of fibrous mass by gravity. Level of the material in the digester and the cooking temperature control the capacity of the digester. These digesters have distinct zones like impregnating, heating, cooking, washing etc. across their height. Certain systems of this type are capable of carrying out vapour and/or liquor phase cooking and two stage cooking also. Since systems of this type do not require transportation of the fibrous material by mechanical means, the possibility of mechanical damage to fibres is completely eliminated. Isotopic measuring device is used to control filling level of the digester.

(*iv*) *Vertical Upflow Type*:—Digesters of this type have a vertical cylindrical vessel where the fibrous material is forced to move upward. Important features of these digesters are:

(a) Hydrostatic head in the digester favours rapid penetration of cooking liquor into the fibrous material before its cooking starts.

(b) These permit gradual rise of temperature and thus offer added scope for more uniform cooking.

(c) Discharge of the cooked material becomes self-controlled. Thus, eliminating the requirement of instruments for its control as is the case with vertical downflow type.

(d) Capacity of these digesters can only be controlled by altering cooking temperature.

(e) These digesters pose special problems with regard to material feeding and distribution in them. Impco (4) digester uses a single turn helicoid screw type perforated piston which rotates for a portion of a turn after each vertical stroke to achieve uniform distribution of fibrous material in it.

2 D. *Discharging Mechanism* :—Different systems employ different discharging devices of special designs. The choice of discharging mechanism is also governed by the type of pulp to be produced. The Pandia system uses a chemipress (a double lead tapered screw) for discharging the fibrous materials treated at atmospheric pressure, otherwise, it uses a rotating impeller discharger with an adjustable orifice. For discharging superior type low yield pulps it prefers a rotary valve. Though in most systems discharging is done continuously, there are systems where it is done intermittently also. Escher Wyss system uses a conical blow valve automatically but intermittently opened by a gamma ray level controller. The Defibrator system uses horizontal twin screws over which is a slow revolving horizontal agitator. Celdecor-Kamyr system uses a blow valve with a rotating scrapper device with blades sweeping the inside surface of the valve. Grenco and Bauer M & D systems use rotary valves. Here again the discharging mechanism should be such that it causes minimum mechanical injury to the fibres. This becomes an important consideration when discharge is made at the cooking temperature and manufacture of fully chemical pulp is involved. The use of a rotary should normally be considered most efficient for this purpose.

3. Batch Versus Continuous Cooking:

A continuous system not only streamlines pulp mill operations, but also offers many advantages over the batch system of cooking. These are :—

(1) An improved and uniform quality product.

(2) Higher pulp yield with reduced rejects and lower cooking chemical consumption.

(3) Greater steam economy because cyclic heating and cooling of digester body is eliminated, cooking is carried out at lower material to cooking liquor ratios and higher pulp yields are obtained. But in continuous cooking systems, pulping is generally affected at a higher temperature. Therefore saving in steam consumption per tonne of pulp is decided by the resultant of these component forces.

(4) Uniform requirement of steam, fibrous raw material, cooking liquor, etc. Thus, reduced storage requirement and uniform load on boilers. This means a lower boiler evaporation capacity requirement for new units and higher boiler efficiency for the existing ones.

(5) More efficient utilisation of digester blow off steam at a lower equipment cost because of its continuous availability.

(6) Higher and at the same time more uniform rate of cooking results in a shorter cooking time and thus a smaller digester capacity requirement.

(7) Higher concentration of spend liquors because of lower material to liquor ratios and higher cooking temperatures results in reduced load on evaporations and lower steam requirement for liquor evaporation.

(8) Smaller space and building requirement.

(9) Greater opportunity for employing automatic control over the pulping process. Thus, reduced personnel requirement with more dependable and smooth running of the plant.

(10) Inherent ability of the system to heat the fibrous material almost instantaneously to digestion temperature which is a condition highly desirable for the manufacture of chemi-mechanical pulps from certain processes. Batch systems fail to satisfy this requirement.

(11) Offer greater scope for the utilisation of two or more stage pulping processes effectively.

(12) Require lower overall capital investment provided the plant capacity is not too small.

Continuous cooking systems have the following disqualifications also over batch systems:

(1) A break-down in the system results in complete shut-down of the plant.

(2) At the start-up of the plant some product is invariably off standard.

(3) They are certainly more complicated and need more skilled hands to handle them.

4. Added contributions of Continuous Cooking Systems

Certain continuous cooking systems incorporate added novelties like diffusion washing and defibrising of the cooked material at the digestion temperature prior to its discharge.

4.1. Diffusion Washing at Digester Temperature:— It is now well established that the fibres of cooked pulp are very fragile as long as they remain at cooking temperatures (above 110°C) in the presence of cooking liquor, and are liable to a considerable damage if blown from the digester at the cooking temperature which is generally much higher than the temperature used in batch cooking. In order to eliminate the detrimental effect of high temperature on pulp quality, one of the most widely applied cooking system cools the material down to say 80—90°C before blowing it off from the digester. Also, it is now quite certain that washing at elevated temperatures not only improves washing efficiency but also reduce the bleach requirement of the pulp by avoiding reprecipitation of the dissolved substances on the fibres. To meet both these objectives washing of the cooked material prior to its discharge from the digester has been put into use commercially. There are a number of Kamyr continuous digesters, design of which incorporates this novel approach to produce pulps of improved quality. Impco digesters are also equipped to carry out countercurrent washing in them.

4.2. Defibration At Cooking Temperature:—It has been reported that the power requirement for defibrising lignocellulosic materials steadily decreases with the rise in defibrising temperature and there is a sharp drop in power consumption when the material reaches in the temperature range of 300—350°F. This shows that there is a critical temperature (somewhere between 300—350°F depending on the material) at which the middle lamella loses its adhesive property. Naturally, if the material is defibred at or above the critical temperature the power requirement will be much lower than what it would have been for defibrising at 200—210°F. The defibration system takes advantage of this behaviour of middle lamella and thus defibres the materials at the digestion temperatures. This system is attractive from this angle especially to manufacture ultra-high yield pulps from processes based on high temperature cooking for a short duration.

5. Continuous Pulping in India: Continuous pulping of fibrous raw materials, a subject of great interest of the past, a favourite technique of today and an indispensible friend of tomorrow, did not fail to attract attention of Indian Pulp and Paper Industry also. The first plant having a capacity of 24 tonnes of pulp per day from Celdecor Pomilio process was installed in Bihar about 15 years ago. After a lull of about ten years, a serious thinking on this vital aspect of pulping started again somewhere around 1960. The second plant was put into commission in 1961-62 in Mysore to produce 35 tonnes of pulp per day from bagasse using Pandia Continuous Digesting System. Soon after another Pandia unit came up in Madras for the pulping of bagasse. At present for the pulping of materials like bamboo, hardwoods and jute sticks two Kamyr digesters each having a capacity of 150 tonnes of pulp per day are under installation in West Bengal.

The aforementioned gives an impression that our industry is late in adopting this method of pulping by at least a decade. In fact this delay was quite natural and in no way reflects on the entrepreneurship of the industry because :

(a) Its activities have been concentrated on the manufacture of fully chemical pulps whereas continuous digesters were first largely employed for the manufacture of course pulps mostly in the high yield range.

(b) Its fibrous raw materials have been different from those which have largely been pulped by this technique.

(c) Its requirement is for comparatively much smaller capacity plants than of those countries where continuous cooking is more popular.

(d) In many cases it is obliged to use a number of fibrous raw materials in varying proportions depending upon their relative availability, and in other cases where one single raw material is used it has fully been aware of their limited potential availability for its evergrowing needs.

Such factors have so far hardly left enough inventive before Indian Pulp and Paper Industry to warrant the entrepreneurship of trying an equipment in its early stages of development which has never been used before for pulping its raw materials especially when alternate well established equipment, though of lower efficiency, together with trained personnel are easily available.

6. Prospects for Continuous Pulp Manufacture in India:

Continuous pulping technique is of very high potential value to the Pulp Industry of India because :

(a) Steadily growing utilisation of agricultural fibres. Agricultural residues are much bulkier than bamboo or woods and thus require about 50% more of digester capacity, higher material to liquor ratios and higher steam requirement for cooking and evaporation of spend liquors in batch cooking. A continuous system has inherent ability to process these materials much more efficiently that a batch system.

(b) A very important of Indian pulp mills is that all of them are integrated pulp and paper-making units and hence do not have the problems faced by the pulp mills which offer pulp in the market. Thus, any variation in pulp quality, which may be mostly confined to the start-up periods of continuous cooking system, can quite conveniently be accommodated by an integrated pulp and paper mill.

(c) Continuous cooking systems are equally efficient also for the pulping of mixed fibrous materials, requiring more or less similar cooking conditions. As a rough guide, bamboo, woods and jute sticks can be classed into one category and bagasse, straws, grasses and reeds into another category. One unit based on bamboo and hardwoods and the other unit utilising bamboo and jute sticks are coming up soon.

(d) Pulping capacity of most of our mills has already exceeded 100 tonnes of pulp per day. Moreover, a number of mills have already in hand major expansion schemes and it will not be long for them to have a capacity of over 150 tonnes per day each. Thus, mills are now in a better position to go for reasonably large size continuous pulping plants.

(e) To manufacture ultra-high-yield chemi-mechanical pulps to make up at least partially the deficiency of conventional groundwood pulps. Continuous pulping systems are especially attractive to manufacture these grades of pulp from most of the processes.

(f) To manufacture cheap grades of pulp for producing products like corrugated boards, container boards and many other types of boards which find their increasing application in various fields. Continuous pulping technique offers an added incentive to manufacture these types of pulps.

7. Conclusion: It is now long since the continuous pulping technique has successfully passed from experimental and development stage. Well established continuous cooking systems are now available for pulping practically all types of ligno-cellulosic materials to manufacture all grades of pulps ranging from rayon to corrugating and newsprint in the full spectrum of yield range by most of the processes, of course, excluding calcium base acid sulphite process. A spectacular increase in its application and thereby complete overshadowing of the age-old batch digester system is inevitable in the years ahead. It is hoped that future designs of continuous pulping systems will continue to offer additional advantages and soon these will become a piece of standard equipment in the Indian Pulp industry.

8. Acknowledgment: Thanks are due to the Management of Tribeni Tissues Private Ltd. for allowing the author to publish this paper.

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