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Pulping of Bagasse

PRODUCTION OF BAGASSE

The pulp and paper industry in the world depends on wood fibres for 85-90% of its raw materials.

Among various wood fibres that of needle leaf trees is regarded as of especially good quality.

This kind of tree, however, is hardly to be found either in the tropical or subtropical zone.

On the other hand these zones have good fibres as substitutes for wood, such as bagasse, the subject of this paper, cereal straw, bamboo, reed, abaca, sisal, hemp, flax, jute, kenaf etc.

It will benefit the nation in industrializing her and preventing the outflow of foreign currency from her to decrease the import of paper and pulp by utilizing the national resources.

Among the above-mentioned fibres bagasse exists in the broader region: India, Southeast Asia, the islands in the Pacific Ocean to Hawaiian Islands, Central and South America and so on. Meanwhile bagasse is the strained draff of sugar cane. Bagasse which is left behind by extracting sugar out of sugar cane is mostly dumped as it is or used as fuel. Needless to say, it would be much more profitable to replace the fuel in the sugar mill by fuel oil and to utilise bagasse with some process, that is, to pulp it.

FIBRES OF BAGASSE

Sugar cane, as well as straw and bamboo, is made of grass fibres, and belongs to grasses (Graminaceae).

Now let us compare bagasse fibres with other vegetable fibres so that you may see how excellent bagasse is as raw materials for pulp.

Bagasee is actually used in many countries as raw materials for various kinds of paper.

Masaya Matoba, The Japan Plant Association.

The figures concerning bagasse on the next table are those of depithed one (to be mentioned later).

In Japan that is poor in wood resources the use of broad-leaved trees for pulp material has been increasing and has come to replace that of conifers; some kinds of paper are made up of 100% broad-leaved trees.

Now let us compare bagasse with broad-leaved trees.

Fibre length and width, especially their ratio have great influence on the strength. There is little difference between bagasse and broad-leaved trees on these points.

As for pentosan bagasse has fairly more of it.

The fact that it contains such pentosan has such advantage as: it gives more strength to paper (breaking length, bursting ratio, and folding number); it makes breaking easy and decrease the consumption of electricity, while the disadvantage is that it makes paper hard and less opaque. Therefore, some counter-measures should be taken if necessary.

Ingredient of Bagasse

Sugar cane	water	62-63%
	sugar	11-12%
	bagasse	26%

What is shown here as 26% is called green bagasse. The sugar is mostly poly saccharides, and contains a little mono saccharides.

Green bagasse water 50%
(accordingly 13% of sugar cane)

fibre & pith 50%
(accordingly 13% of sugar cane)

That which is left behind after this 50% water is removed is called bone-dried bagasse, and this consists of fibre and pith (and some admixture) as is shown by the above figure.

Bone-dry bagasse Fibre 65%
(8.5% of sugar cane).

pith 25%
(3.2% of sugar cane).

water-soluble substance 10%
(1.3% of sugar cane).

If we consider pulp yield to be mentioned later (different according to the pulping process) on the basis of the above figures, we could estimate the amount of pulp (kg) to be obtained from one ton of green bagasse.

COLLECTION OF BAGASSE

It is most important that pulp material should be obtainable intensively and cheaply. As for wood, for example, it is more convenient to choose such woods as with only one kind of trees.

Another great advantage of bagasse is that sugar cane grows fast. In the case of wood it takes at least forty years to have grown up trees, and consequently long-term plantation is essential to secure raw materials for the pulp mill, whereas bagasse grows up in a year or a year and a half.

However, consideration should be given to the distance between the sugar mill and the pulp mill. The shorter the distance is, the less is the expenditure for transporting bagasse.

But the conditions of location for the sugar mill do not always correspond with those for the pulp mill.

The paper mill requires 200-500 tons of good water to produce 1 ton of paper, though the figures vary according to the kind of paper, and also it has to drain and discharge almost as much water. Some methods of pulping could give rise to the problem of public hazard.

Another question lies in labour management. Generally speaking the sugar mill operates only half a year (the harvest season), and in the other half of a year is consolidates itself.

On the other hand the pulp mill runs 24 hours a day (3 shifts) and keeps running all the year round except a few holidays.

Therefore, it is made necessary to store bagasse in the half year of the harvest season for the use of the other half of the year.

STORAGE OF BAGASSE

Besides the stock for half a year, running stock for every day should also be secured near the pulp mill. In case the pulp is at a long distance from the sugar mill, transportation becomes necessary. The problem is, however, that bagasse is so bulky that it takes 3-5 m^3. of capacity per 1 metric ton when loaded in bulk.

If bagasse is made compact as explained in the following, it takes less capacity to our convenience.

Bagasse has remaining sugar and water in it, which are apt to ferment and degenerate; and it may do well to take off as much water as possible.

In pulping compactness is also necessary to fill the digester with it.

The process of storage may be divided into three general groups :

(i) bulky process
(ii) baling
(iii) briquetting

The specific volume becomes smaller in that order, though the expense becomes the greater.

BULKY SYSTEM

Generally after depithed bagasse is treated with antiseptic agent, it is piled up to a height of 15 — 20 meters out of doors without any roof over it. It is inevitable that a part of it should change in quality and be lost, but the cost of equipment is low. Dump-trucks are needed for transportation and conveyors for loading. This bulky system is not suitable for transporting bagasse to a distant pulp mill.

BALING

Bagasse is compressed by the baling machine (to extrude with piston for shaping), fastened by wire and made into a proper size; for example, 0.3m. $\times$ 0.3m. $\times$0.5m. is an ordinary size. It still contains 50% of water (little decreased by this process), and should be stored in a well-ventilated place. The specific volume per ton is in the region of 2—2.5 m^3.

To cite an instance of the machine capacity 1.9 tons/24 hr., motor 30 hp, and 1 person per 3 tons (including water) from receiving to loading of bales.

In Baling, both equipment and handling are easy, but as water is still contained, bagasse is yet liable to ferment and degenerate.

BRIQUETTING

Usually after bagasse is depithed, it is dried and formed into sticks with a diameter of 75-110 mm. (about 30 cm. long). Water is decreased to 7-9% and the specific volume also lessens to 1.1 — 1.2 m^3 per ton.

An example of this equipment: after depithing bagasse is dried by the suspension dryer (flow-drying by oil; the rate of contained water could be controllable between 5 and 20% and made uniform by cyclone) and put to the briquetting machine.

In addition to the fuel for drying, the expense for equipment is great. However, as the water contained in bagasse is little, the bagasse gets less bulky and hardly changes in quality.

PITH

As mentioned above, bagasse consists of fibres and pith; fibre cells propex are contained in the epidermis and vascular bundles, and most of the pith makes up parenchyma cells.

In depithing most of the vessels in vascular bundles are taken off at the same time.

Pith is the non-fibre part; its cells are wide and less than 0.4 mm long, and therefore the ratio of fibre length to width is small, namely, not larger than 6.5. Compared with that of the fibre part (85-100), this is extremely small and of no use for giving strength to paper.

To compare the fibre with the pith in point of the chemical composition, the pith has a little more of ash and substance soluble in hot water than the fibre, and little — cellulose. Both have about the same amount of lignin and pentosan.

One of the physical properties of pith as seen in its form, is, great absorbency. Consequently it contains much remaining sugar and water-soluble substance, which help to consume chemicals in the pulping process.

In caustic cooking it gets wet and swollen by strong alkali and turns gelatinous, which in machining process causes the wire and felt to get clogged and clinging to the press roll makes drainage poor and paper less strong. Moreover, since pith has dirty colloid soil absorbed in it, a great care must be taken in bleaching so that paper may not have dust in it.

As we have seen, depithing is an essential condition in producing pulp, especially chemical pulp (cooking needed).

Concerning depithing for machine pulp there arise the questions of yield to quality and facility of operation. These matters are to be commented on later; but to say briefly depithing might as well be graded according to the quality of paper; fine quality, medium and low grade.

DEPITHING

Depithing may be divided broadly into two groups; dry process and wet process. Either process takes place after beating.

In the dry process broken bagasse is beaten by hammer mill or something like that and the pith is sifted by the screen. In this process the sticking dust is also weeded out and can be used as fuel.

In the wet process bagasse is agitated and broken together with water (consistency : 5 — 10%) by the hydrapulper or something like that. Then pith is screened out.

Though a great deal of water is used in this process, the fibres are not damaged during the process and show a high rate of depithing.

The influence that the rate of depithing has on chemical pulp is shown on Table I.

TABLE I

	Bagasse	Broad-leaved tree	Rice straw	Bamboo
Fibre length mm.	0.8-2.8	0.7-1.6	1.1-1.5	3-4
Fibre width, u	10-34	20-40	9-13	14
— Cellulose %	40-43	38-49	33-38	50
Pentosan %	30-32	20-25	27-32	16-21
Lignin %	19-21	18-25	17-19	22-30
Ash %	2	1	6-8	1-3

Note : Different growing districts may give a little different figures.

FILLING

In making chemical pulp cooking in digester is necessary. However, bagasse is so bulky in its form that the amount for filling is much smaller compared with wood chips.

The rate of liquid is 4—5 : 1 in the case of wood, whereas in bagasse it is 10—12 : 1.

It means that surplus liquid is heated and the expense for steam becomes greater. And the material massing through digester is apt to channel. To prevent it, the rotary digester or the Pandia horizontal continuous digester by screw conveyor is advisable for use.

PULPING

CHEMICAL PULP (See Table 2 & 3)

In the case of wood, each of alkali, acid and neutral cooking is in use, but as for bagasse alkali cooking is overwhelmingly used, and the other two are seldom seen in use.

Let us see some of the typical processes of alkali cooking (a) — (d) and then the other cooking processes.

LIME PROCESS

Cooking takes place with CaO of 8 — 12% of bagasse bone-dry weight and with the low pressure of 1 — 3.5 kg/cm².

The pulp produced by this process is hard bleachable one and yellowish, and is not suited to bleach. Accordingly it can be used only for wrapping board, corrugating material and so on. This process is inferior to the next soda process.

SODA PROCESS

In this process NaOH is used and as bleaching is possible, materials for various kinds of paper are produced. This process is in actual use not only for bagasse but also for cereal straw, bamboo etc.

The amount of NaOH is : 7 — 9% of bagasse bone-dry weight to make pulp with yield of 70% and 12 — 20 % of the same for the yield of 44-48%.

KRAFT PROCESS

This process might be regarded as a variation of the soda process, as a part of NaOH in the soda process is replaced by Na_2S here.

The cooking conditions are also similar to those of the soda process; the pulp by this process is good in yield, strength and bleachability.

The following is an example of cooking conditions :

NaOH + Na_2S 14 — 16% (of bagasse bone-dry wt.)

Temperature 170°C × 2 hours

Yield unbleached 53 — 55%
bleached 48 — 50%

Rate of bleaching chlorine 8 — 9%

The trouble is that the kraft process costs a great deal for constructing the mill. If recovery equipment is set up, the expense becomes greater. On the other hand as chemicals and fuel are economised the direct expense for production becomes smaller.

Generally speaking the kraft process is suitable for a large scale plant. Whether recovery equipment should be installed or not depends on the payability of the plant, that is, chemicals, fuel, electricity, labour cost, repayment to the expense for equipment, interest rates etc.

As things stand today in Japan it is said that plants with more than 60 tons of daily output alone can find the recovery equipment pay.

ALKALI—CHLORINE PROCESS

Celdecor-Pomilio process is a typical example of this process. It was developed in Italy for cereal straw and is suitable for bagasse, straw and grass as well.

In the region where NaOH cannot be obtained at a low cost, what is generated by the electrolyzing sea water is used instead. But as Cl_2 is also generated in this case, it goes well to use both of them in proper balance of the rate of generation of NaOH and Cl_2.

That is characteristic of this process.

After light alkaline treatment in the continuous cooking digester, washing, pressing and breaking take place, and then with Cl_2 blown into chlorination tower lignin the pulp is changed into chlorinated lignin.

That which comes out is washed in acid and as the third process with caustic treatment lignin is melted away and it is pulped. Then after alkali washing, screening and the decker it is sent to the continuous bleacher.

As for bleaching agent, hypochlorite obtained from Cl_2 generated by electrolysis and lime is used.

From the view point of equipment, since the digester needs no pressure, the digester itself is not expensive, but if electrolizer is annexed, it costs much. The rate of chemicals used being high, the direct expense is great. The above mentioned are all concerned with alkali liquid, and to follow :

NEUTRAL SULFITE PROCESS

In this process Na_2SO_3 is the main chemical and as buffer solution Na_2CO_3 is used.

Since this process cannot fully attack the wax covering the epidermix of sugar cane, hemicellulose remains unattacked in the pulp, and therefore, the yield of unbleached pulp is great, though shives and dust show much. It is good in whiteness, but poor in strength and consumes much chemical.

It has not been reported that this process was ever put in practice.

The above are chemical pulp, whereas from the point of producing equipment it is divided into batch process and continuous process.

BATCH PROCESS

The typical example of Batch process is the spherical digester and the following is an instance of the flow sheet by this process.

TABLE 2 — COMPARISON OF BAGASSE PULPING PROCESS

Pulping Process		Soda Process & Kraft Process	Mechano — Chemical Process	Alkali-Chlorine Process (Celdecor-Pomilio Process)	Neutral Sulfite Process	RGP Process & Cold Soda Process
Use of Pulp	Unbleached*	Board, Wrapping paper	Same as the light	Same as the light	Newsprint, board, Wrapping paper	Newsprint
	Bleached**	Fine quality paper, greaseproof paper	Same as the light	Same as the light		
Cooking chemicals		sodium hydroxide or (sodium hydroxide (sodium sulphide	Same as the light	Sodium hydroxide	sodium sulphite sodium carbonate	No chemicals or sodium hydroxide
Yield (the depithed)	Unbleached*	60-70%	65-75%	65-75%	60-70%	80-90%
	Bleached**	44-50%	48-50%	46-48%	48-50%	
Characteristics	Equipment	1) Batch (rotary digester) or Continuous (Pandia process) cooking etc.	1) Cooked with pulper at atmospheric pressure & with investment comparatively small	1) Continuous-multistage pulping process, with equipment operation comparatively simple.	1) Equipment is simple to Soda process	1) Equipment like in wood RGP or cold soda CGP will probably do
		2) Possible to relieve cooking chemicals	2) With simple operation equipment can be kept well easily	2) Profitable in case of annexing electrolysis mill	2) Recovery of cooking chemicals is difficult	

Quality	1) Kraft Process is better than Soda process in yld. bleachability & strength	1) High yield pulp with strength & uniformity, is obtained	1) Even with low state of depithing, clean bleached pulp can be produced	1) Colour of the unbleached is better than by alkali process, but strength is inferior 2) Bleachability of high bleach is inferior to that of Kraft process	1) The unbleached is not good in colour, light bleach is necessary for newsprint 1) The unbleached is not good in colour, light bleach is necessary for newsprint
Problems	1) Equipment for chemicals recovery expensive 2) It should be considered that properties of cooking waste liquor differ from woods	1) Consistancy of waste liquor being low, the question lies chemical recovery	1) Fixed cost becomes high 2) The issue depends on the cost of industrial salt by electrolysis and electricity	1) It costs much for chemicals	1) Some problems regarding equipment and operation still remain unsettled.
Instances of Operation	Now operated in India, Formosa, Cuba, Puerto. Rico, etc	Now operated in India,Formosa, Mexico, etc.	Now operated in India, Phillipines, Brazil, Mexico, etc.	Instances of operations are unknown (Once done in Formosa)	Instances of operation unknown
Remarks	1) Practised for long years, & with various modifications	1) Developed in the U.S.A. (made public in 1949)	Development in Italy for pulping straw	1) Developed in Argentina	1) Examinations required pertaining to patents

Note: **** show the use and yield of bleached and unbleached pulp.

TABLE 3 — COMPARISON OF BAGASSE PULP MANUFACTURE — PHYSICAL UNITS.

(Cooking chemicals not to be recovered except in kraft process)

Pulping process	Soda Process			Kraft process (recovered)				Neutral Sulfite Process			Alkali chlorine process		Mechano-chemical process		
											Bleached				
	Board	Unbleached	Bleached	Board	Unbleached	Bleached chemicals purchased	Electrolysis	Board	Unbleached	Bleached	Chemical purchased	Electrolysis	Board	Unbleached	Bleached
Yield (% to depithed) bagasse	70	55	50	70	55	50	50	70	60	50	48	48	75	60	50
Material bagasse (depithed bagasse AD kg.)	142	182	200	142	182	200	200	142	166	200	208	208	134	166	200
Chemicals (kg.)															
Soda ash								3.5	7	8.5					
Sodium sulphite								9	20.5	24.5					
Sulphate of soda				4	8	12.5									
Limestone				8	16	20	22								
Sodium hydroxide	10	25	27			2				3	22.5		8	18	22
Sulfur							2								
Chlorine			8			6				7.5	16.5				11
Stacked lime			3							2	2	2			3
Salt						13						40			
Electricity (KWH)	20	20	35	40	40	50	15	20	20	35	40	100	25	30	45
Steam consumption	120	140	300	430	450	600	600	120	140	300	210	300	250	300	350
Formation on alkali recovery	—	—	—	300	400	430	430	—	—	—	—	—	—	—	—
Net consumption	120	140	300	130	50	170	120	120	140	300	210	300	250	300	350
Water (m^3)	7.5	7.5	20	10	10	25	25	7.5	20	20	44	44	7.5	7.5	20

Compared with the continuous process to be mentioned next, the yield is smaller. The diameter of the digester is usually 12 or 14 feet, with pressure of 2 — 4 kg/cm^2 2-4 hr/batch. The rate of liquid is 10 — 12; the volumetric efficiency of the digester, being 90 kg/m^3, is much lower than 160 kg/m^3 of wood.

CONTINUOUS PROCESS

There are Pandia Process, American Defibrator Process, the above-mentioned Celdecor-Pomilio Process and so on. As mentioned above, Pandia Process is a good cooking process suitable for bagasse, as it has no fear of channelling.

However, there are some problems as follows :

1. Maintenance expense should be taken into account for the worn-out rotary part of digester.
2. The amount of power used for digester is large (for turning screws etc.)
3. Since the shape of digester is tube-like, cooking time is limited.

Defibrator Process

The outline of this process is as follows :

1. head box 2. clear water 3. baled bagasse 4. conveyor 5. continuous hydrapulper 6. tank 7. white water 8. filter 9. white water tank 10. pith 11. depithing & dehydrater 12. return chute 13. wetting tube 14. liquor injection 15. permeating tube 16. screw feeder 17. digester 18. Defibrator and 19. unbleached pulp.

This process is suitable for high yield of medium and low grade paper.

The problem is that it requires much power for the screw and feeder and that it costs much owing to the wear of the rotary part of digester.

MECHANO-CHEMICAL PULP

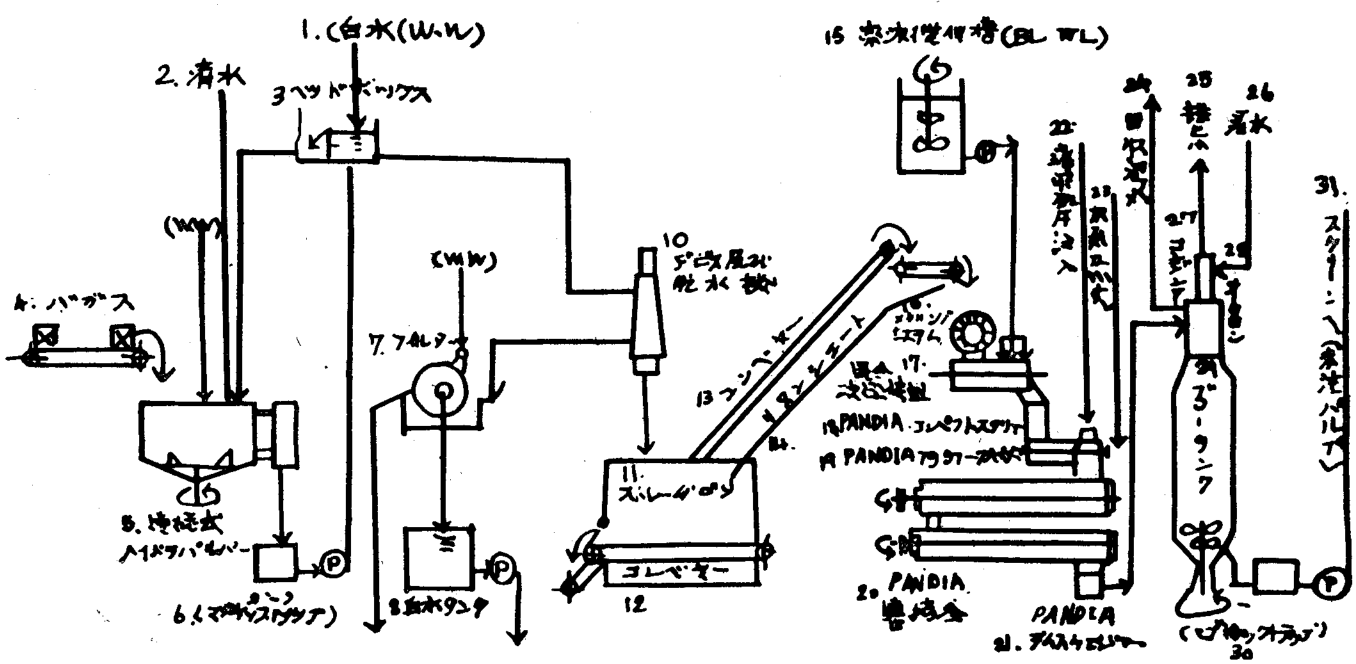
As the above-mentioned chemical pulp is cooked with alkali liquor under pressure in digester, parts of cellulose and hemicellulose are attacked.

This process is to make the chemical reaction slower with the help of mechanical action.

In the specially-planned hydrapulper the materials go through the eddies by rotary runner, while in this equipment steam and liquor (NaOH or NaOH + Na_2SO_3) are added and the materials are cooked slowly at atmospheric pressure.

(A) PANDIA 連続蒸解方式

図7-5 PANDIA Process



1. white water 2. clear water. 3 head box. 4 bagasse 5. continuous hydrapulper 6. tank (magnetic trap) 7. filter 8. white water tank 9. pith 10. depithing and dehydrater 11. storage bin 12 conveyor 13. conveyor 14. return chute 15. liquor agitator 16. metering system 17. mixing permeater 18. compact screw 19. screw feeder 20. continuous digester 21. discharger 22. liquor pressure and injection 23. heated steam 24. recovery warm water 25. exhaustion 26. clear water 27. condenser 28. cyclone 29. blow tank 30. (Magnetic trap) 31. to screen (unwashed pulp).

The pulp thus produced excels chemical pulp both in yield and strength.

MECHANICAL PULP

In the case of wood 'mechanical pulp' reminds us of what is called ground wood pulp, which is made by grinding peeled round timbers.

Recently RGP (Refiner-ground-pulp) Process in which wood chips are ground by the refiner has made a remarkable progress. The pulp that is lightly treated with chemicals before hand is also classified into this category.

In the case of bagasse it is relevant to do this light treatment with chemicals and the refining in combination.

In Japan deep researches have been made concerning the matter.

Since mechanical pulp is used as materials for medium and low grade paper, low price and high yield are to be required.

Consequently such complete depithing as in chemical pulp is not necessary.

In Japan they have succeeded in making materials for newsprint paper from undepithed bagasse.

This process aims at economy of power for the refiner and improvement of quality by soaking bagasse in cold alkali liquor in order to make it a little softer before refining.

Bagasse fibres are indeed harder than wood and the above process covers this defect.

To make it materials for newsprint paper it is bleached to brightness 50 G.E. and about 20% of conifer bleached pulp is added to it to give it strength.

Needless to say, depithing makes it of better quality.

Only when high yield is aimed at the cost of its quality this process should be adopted.

CONCLUSION

The above mentioned various pulping processes are shown on Table 2 with their merits and demerits, and the physical units of producing the pulp on Table 3.

From bagasse almost any kind of paper can be made. In Japan experiments have shown the possibility of excellent quality paper and production of cement bag paper is now on researches and quite promising.

Besides, various kinds of paper — medium and low grade paper and general wrapping paper are made from bagasse. The question lies in how to make a choice of the process and equipment suitable for the situation.