Energy management in pulp and paper industry

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As we know, pulp and paper industry is one of the most energy intensive industry. However, paper manufacturing process by its very nature is amenable to the incorporation of energy conservation systems. At the projected production of 4.5 million tonnes by the turn of the century, it is expected that the papermaking industry will require about 5.4 million tonnes of coal and about 3 billion units of electricity with 75 per cent capacity utilisation. The ever rising trend of the cost of energy clearly indicates that energy is fast becoming the most expensive input in papermaking.

Energy requirement

Indian pulp and paper mills use external energy in the form of coal, oil, electricity to an extent of 70 percent of their energy needs (30 per cent coming from the burning of internally produced combustibles.) This compares to an average of 40 percent external energy used by the average pulp and paper industry of the industralized world. The reasons for their difference are many. A few are discussed here.

The important sources of energy are as follows:

Source	Approx. Global production (in million metric tonnes/year)
Crude oil	3800
Hard coal	2300
Natural gas	1800
Gasoline	960
Fuel wood	540
Black liquor (Pulping spent liquor)	200

It will be seen from above figures that "black liquor" occupies sixth position in the list of important global fuels. However, small mills do not burn the black liquor which contains nearly half of the weight of the raw material input, whereas chemical recovery in pulp and paper miils, serves three important functions recovery of cooking chemicals, generation of energy from the dissolved organic matter and reduction in environmental pollution. The small sizes of the digesters in small mills are less energy efficient than big ones. Solid waste combustion are not used sufficiently as a fuel. Most of the equipment is old and not designed for energy conservation.

The paper industry requires about 85 per cent low grade energy and 15 per cent high grade energy. The low grade energy is required in the form of steam for process heating. The high grade energy is in the form of electricity which is mostly used as motive power for drives. It is obvious that purchased energy, especially in the form of electricity is for more expensive than burning of agricultural residues.

The pattern of energy consumption varies from mill to mill depending upon individuals attempts in this direction and modernisation of the process equipment etc. Table 1 and 2 gives an idea of energy consumption in different section of a mill. The data indicate that about 35 per cent of steam and 11 per cent of the power required in its chemical recovery section and further there is wide variation in energy consumption amongst the paper mills. The specific heat consumption varies from 10.2 to 17.4 tonnes per tonne of paper

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Table 1. Total energy consumption in integerated mill

Section	Average per cent of total energy
Pulping	34
Recovery (Boiler, Evaporation, lime kiln)	22
Drying	32

Table 2. Specific energy consumption

Sections	Steam tonne/ tonne of paper	Power (KWH)/ tonne of paper
Chippers		80-120
Pulp mill	2.9 - 3.9	60- 50
Bleach plant	0.3 - 0.4	90-130
Paper machine	3 - 4	470-550
Chemical recovery	2.5 - 4.0	120- 80
Share of chemical recovery in consumption (%)	35	11.0

and specific power consumption 1305 to 1947 KWH per tonne of paper. The variation in specific consumption is largely due to raw material mixture, product mix, coal quality etc. The wide variation in consumption figure from mill to mill indicate that there is enormous scope for conservation of energy.

Energy cogeneration

Today mill managers want to save money at all stages of production. One area which may help them is cogeneration. Cogeneration offers increased operational efficiency and reduction in emissions. It allows a mill to employ advanced technologies for disposal of waste products Paper mills offer numerous fuels such as waste fibres, unburnt coal, bark, chip dust etc. Therefore they are excellent candidates for cogeneration. Typically cogeneration involves steam turbines and boilers in various combinations and configuration alongwith their associated auxuillary and control equipment. Cogeneration allows the mills to address the environmental pressures while upgrading the efficiency of their equipments. The advancement in cogeneration have led to a considerable reduction in purchased energy over the years (taking 1973 as the begining for configuration). This will be quite clear from data reporduced in Table 3. The reduction is about 47 per cent as compared to energy consumed in 1973 (assuming 100 per cent purchased energy consumption). From Table 4 it is understood that self supply of energy from mill waste is considerably high and can be generated at the mill site, if utilised completely. Trends in the industry's energy consumption are shown in Table 5 & 6.

Energy conservation

The point of energy conrervation in small pulp and paper mill based on straw plus, imported waste (cuttings) could be many and actual measures would depend upon the overall set up of the mill with respect to process equipments installation and maintenance. Installation of blow heat recovery system in the digester, high use of pressure (9-10 kg/cm^2) steam preferably

Table 3. Consumption of total purchased energy per ton of paper and paper board production

Year	1973	1975	1980	1985	1987	1988	1989	1990	1991
10^3 Kcal	4947	5531	4063	2900	2822	2837	2806	2764	2646
1973=0	100	112	82	59	57	57	57	56	53

Source = Ministry of International Trade and Industry

Note = In terms of Cal fuel oil = 9,700 Kcal/l.
elec power = 860 Kcal/KWH, domestic coal- 5800 Kcal/kg and imported coal- 6200 Kcal/kg

Table 4. Energy sources of the pulp and paper industry

		Self supply			Purchase				Energy consumption total
		Spent liquor	Bark	Sub total	Fuel oil	Coal	Elc. power	Sub-total	
1980	10^{10} Kcal	3364	120	3518	6176	139	1034	7394	10912
	Composition of energy consumption	31	1	32	57	1	9	68	
	(%)				84	2	14	100	100
1991	10^{10} Kcal	4426	196	4657	4826	1920	945	8334	12991
	Composition of energy consumption	32	2	36	37	15	7	64	
	(%)				58	23	11	100	100

Source = Japan Paper Association

Note = Sub-total includes other minor energy resources

Table 5. Trends in Industry's electric power consumption (in mil KWH)

Year	1980	1985	1987	1988	1989	1990	1991
Total consumption (A)	24207	24176	25590	27718	29719	31217	32153
Mill own generation							
For pulp production	5739	4701	6333	7065	7964	8418	8734
For paper production	4577	4959	6729	7549	8362	8866	9164
For paper board production	1686	1913	2326	2745	3079	3224	3264
Total (B)	12002	11574	15388	17359	19406	20508	21162
Purchased							
For pulp production	4002	3395	2158	2287	2220	2394	2478
For paper production	4931	5660	4663	4869	5002	5219	5384
For paper board production	3092	3545	3381	3208	3012	3096	3129
Total	12025	12600	10202	10359	10313	10709	10991
((B)/(A) x 100 (%)	49.6	47.9	60.1	62.6	65.3	65.7	6.8

Source : Ministry of International Trade and Industry

Table 6. Trends in the industry's heavy oil and coal consumption

Year	Heavy oil consumption (in 1000 kl)				Total coal consumption (in 100 tons)
	For pulp production	For paper production	For paperboard production	Total consumption	
1980	2048	2697	1622	6367	238
1985	1276	1771	1279	4325	1076
1987	1294	1884	1288	4466	1866
1988	1402	2056	1385	4843	2259
1989	1486	2201	1444	5130	2661
1990	1517	2145	1496	5158	3071
1991	1523	2160	1292	4975	3098

Source = Ministry of International Trade and Industry

in the digester, use of hot cooking liquor (80°C) for reduction of presteaming time and to prevent excess steam condensation, optimisation of the amount of air in the boiler for improved combustion efficiency and reduction in the difference between the dry solid content of paper sheet after suction press and pop reel etc are a few points to list that may result in substantial energy conservation.

Process innovation for energy conservation

Development in pulp and paper production coupled with increasingly growing consiousness about environment protection call for increased use of high yield pulps in papermaking furnishes. High yield pulps are rich in lignin which is hydrophobic in nature. As the amount of lignin increases there is deterioration in strength properties (bonding strength) and the pulp requires more energy in mechanical/chemical treatments These draw backs limit the application of high yield pulps in papermaking furnishes. Therefore in order to enhance the usage of high yield pulps in papermaking furnishes and help to produce more paper from same unit of raw material, it is necessary to improve their mechanical properties and bleachability at energy applications as low as possible. In this context the problem is central to the hydrophobic nature of lignin. The prime aim is therefore to develop a process to make high yield pulp lignin hydrophilic without impairment in yield to improve fibre swelling, bonded area specific surface area etc and consequently improve the mechanical strength properties and reduce energy requirements.

Singh *et al* have developed a process for modification of lignin in high yield pulp with prime aim to make it more hydrophilic and consequently improve the overall papermaking properties of high yield pulps and thus help enhance their usage in papermaking furnishes.

Their approach has been to activate lignin through pretreatments by chlorine or nitric acid followed by reaction with sodium sulphite and hypochlorite. Tables 7 and 8 give an account of their findings with respect to modification of soda thermomechanical (STM) and soda sulphite thermomechanical (SSTM) pulps of bamboo and cold soda pulp of su-babul and the effect of such modifications on strength properties of high yield pulps. They have concluded that chlorination prior to sulphite treatment followed by reaction with hypochlorite improves the bonding/strength properties. In case of bamboo STM pulp the increase in tensile index was 38 per cent. Burst index increased by over 100 per cent and tear index by 57 per cent. In case of su-babul soda pulp the increase in tensile index was 15 per cent. The final brightness developed by hypochlorite treatment was about 6 units in case of both bamboo and su-babul puls.

Singh *et al* have further reported that pretreatment of *Populus deltoides* cold soda pulp with nitric acid or chlorine before sulfonation with sodium sulphite resulted in much higher improvement in strength properties as compared to the improvement registered by sulphonation without treatments. Pretreatment with nitric acid before sulphonation gave better result in respect of improvement in the strength properties of cold soda pulp, than pretreatment with chlorine (Table 9).

Another approach for modification of lignin in pulps could be a microbiol pretreatment Bhandari *et al* have shown that PFI mill revolution required to achieve same degree of fibrillation and to develop same burst and tensile index were considered low for decayed wood pulp treated with *C. versicolor*. It gave an indication of lower energy requirement, higher burst and tensile index and same tear index could be achieved by 38.9 per cent, 55 per cent and 64 per cent less PFI mill revolution than the control wood pulp. It is reported (Eriksson et al 1982) that 23% of the total energy required In the post refining of thermomechanical pulp could be saved by pretreating the course pulp obtained after first stage of refining with *S. pulverulentum*. Further it was observed that straws and bagasse are better raw material for biopulping. By pretreatment of these material with *P. chrysoporium* followed by cold soda/thermo mechanical pulping 40 50 per cent energy could be saved,

Improved forest management methods will have to be implemented if the industry is to meet the future demand for wood. Tree farming has been envisioned as the answer to the industry's need for adequate supplies of suitable pulpwood, since they rely on machinery, agrichemicals and soil conditioning methods to maintain high timber yields. Biotechnology has the potential to improve the energy scenario of modern tree farming. Developments in fertilizers and pesticides, would allow more efficient tree farms to evolve.

Table 7. Strength properties of handsheets of bamboo STM, SSTM and modified pulps*

Pulp type and modification	Tensile index Nm/g	Burst index $KPam^2/g$	Tear index mNm^2/g
STM- untreated	22.07	0.72	5.37
STM- Chlorine/sulfite	27.94	1.20	5.43
STM- Chlorine/sulphite/hypochlorite	30.48	1.56	7.07
SSTM- untreated	32.38	1.62	7.85
SSTM- Chlorine/sulphite	38.84	2.11	9.02
SSTM-Chlorine/sulphite/hypochlorite	42.96	2.55	8.98

Pulps were beaten in PFI mill at 800 Rev (CSF about 300 ml)

Table 8. Strength properties of handsheets of modified cold soda pulp of Su-babul*

Treatment	Tensile index Nm/g	Burst index $KPam^2/g$	Tear index mNm^2/g	Brightness %	Opacity %
Blank	11.37	0.11	2.35	38.0	99.5
5% sulphite	13.56	0.91	2.57	43.2	99.2
5% Cl_2, 5%So_3, 5% Hypo	28.34	1.10	3.11	44.2	99.5
5% Cl_2, 5%So_3, 5% H, 5% So_3, 2% Hypo	22.2	0.74	2.96	47.7	99.1

* Pulps were beaten in Lampen mill at about 150 ml CSF

Table 9. Effect of sulphonation and nitric acid/chlorine pretreatments on properties of cold soda pulp of *P. deltoides*

Pulp treatment	Pulp sequence (a) %,(b)	Apparent yield density g/cm^3 %	Tensile index Nm/g	Burst index KPam^2/g	Tear index mNm^2/g	Bright-ness Elrepho	Past colour number
Control	100	0.59	31.4	1.71	3.83	50.2	0.6
$Na_2 SO_3$, 5%	100	0.60	34.5	1.88	4.21	48.8	-
HNO_3, 4%/$Na_2 SO_3$,5%	94.3	0.61	44.0	1.97	4.52	50.0	-
HNO_3, 4%/ $Na_2 SO_3$,5%/ HoCl, 5% (c)	91.9	0.61	48.7	2.17	4.71	52.4	3.2
Cl_2 5%/ Na_2 So_3 5%	95.6	0.59	37.7	1.95	4.33	50.3	-
Cl_2,5%/Na_2 So_3, 5%/ HoCl, 5%	92.8	0.58	40.2	1.98	4.50	51	3.4
HoCl, 10%	87.2	0.62	40.4	2.00	3.90	53.5	-
H_2O_2 1%	94.8	0.61	33.0	1.72	4.08	63.5	0.37

a = Percentage of chemicals are expressed on oven dry pulps
b = Percentage yield expressed on oven dry pulp
c = As available chlorine

Fertilizer

1. Developing trees that assimilate naturally occuring nutrients or applied fertilizers mo:e efficiently.
2. Developing trees with nitrogen fixing genses.
3. Improving the symbiotic relationship between tree roots and mycorrhizae to enhance nutrient uptake.
4. Developing microbial fertilizers.

Pesticides

1. Creating tree varieties that resist disease and pests.
2. Using soil bacteria to produce material toxic to insect pests.

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