Energy and material saving by improving first pass retention during sheet formation

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ABSTRACT

Taking 65% First Pass Retention and 70% closure of the Back Water system, significant amount of material is drained and conseqenutly circulated in the form of Back Water.

Based on material balance, an attempt is made to calculate the amount of energy and solids wasted during sheet formation.

The gain in money and energy have been presented taking 10% increase in First Pass Retention.

Laboratory investigations are reported on improvement of retention on different indegenious raw materials using zeta potential measurements.

Introduction

Paper is composed of many constituents, including air giving it the required density, and the water as moisture. The constituents in paper are mainly those which were added in stock while preparing the furnish. The furnish constituents are spread over the forming fabric and the sheet is formed by the simple mechanisms of drainage–filtration–thickening. The line of demarcation among these forming phenomenon is difficult to identify. Initially almost all the material is drained till the first fiber or furnish constituent, having its dimensions bigger than the opening of the forming fabric, is retained by the simple phenomenon of retention by size. Thus the initial retention on forming fabric is by size. As the web develops in z-direction the retention of the material increases due to reduced pore openings. The paper web is also subjected to suction impulses by various drainage elements like Table rolls, Foils, and Suction boxes. The vacuum in these elements is responsible for loss of material which otherwise would have been retained in the web. The material lost in drained water has two cost components, the value of the material itself, and the cost of energy (electrical and heat) spent in preparing the additives in required solution, emulsion, or in slurry form to facilitate their addition into the stock.

The retention on the fabric can be improved by many ways. The first and foremost requirement is to select forming fabric as per the furnish composition. The wire table should also be adequately balanced to perform the gradual removal of water, and drainage/vacuum elements should be designed/selected and controlled as per product quality requirements. In addition to these mechanical aspects, the retention can be further improved by maintaining proper process conditions like temperature, pH, and electrokinetic potential of the furnish.

The use of retention aids is gaining significance in paper industry, however, the electrokinetic balancing

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of the system and proper selection of retention aid are necessary to get maximum advantage from the retention aid.

Retention of Furnish Constituents

Analyzing the dry constituents of furnish at the headbox, paper, backwater and the water going to saveall fiber recovery system for a typical 30 Tonne per day writing/printing grade manufacturing paper machine producing paper from 15–20% long fiber component and rest short hardwood/agriresidue fiber, the various constituents of the furnish appear in paper, backwater etc. as given in Table–1.

The average retention values of the furnish components for the writing printing grades of slow speed machines (upto 200 m/min speed) are filler–55%, Cellulosic fines–65%, rosin–35%, alum–45% and first–pass–retention of 65%. These values can be slightly different in mills within expected limit of variations except in special forming zone designs or typical long fiber furnish of bamboo only.

Cost Burdon due to Poor Retention of Furnish Components.

The money value of the material lost because of lower first pass retention is significant. The overall retention of solids in paper appears to be fairly good and loss looks to be meager. These drained solids sometimes cause process hunting due to their surge input into manufacturing process circuit when their accumulation reaches beyond the tolerable limit of the system.

The cost of papermaking additives is very high (See Table–II.) The use of 1% additives on paper is very common in writing printing grades of papers. Approximately 6 50 Kg rosin per Ton of paper produced remains in back water and this costs Rs. 195/–. Once the rosin comes in contact with alum at pH 5 or less, it will be in precipitated form and cannot give hydrophobicity to fibers when recycled. The dead rosin mass is also responsible for the slime and scales in the approach flow circuit.

TABLE—I

COMPONENT	HEAD BOX	PAPER	BACK WATER	SAVEALL
LONG FIBER No/mg solids	760	750	10	10
SHORT FIBER —do—	8400	7800	600	600
VESSEL FRAGMENTS —do—	155	130	25	25
VESSEL ELEMENTS —do—	25	22	3	3
FILLER mg/mg solids	0.34	0.15	0.19	0.19
CELLULOSIC FINES —do—	0.54	0.32	0.22	0.22
CONSISTENCY %	0.7%	20.0%	0.25%	0.25%
FILLERS ADDED mg/mg paper	0.22	—	—	—
FILLER RETAINED —do—	—	0.15	—	—
FILLER DRAINED —do—	—	—	0.07	—
EXCESS WATER 70% closure	—	—	89.0	89.0
SOLIDS mg/mg	—	—	—	0.22

TABLE—II

FURNISH COMPONENT	COST PER MT Rs.	FPR %	MASS IN B/W Kgs/ T paper	COST OF MASS LOST IN B/W Rs/T Paper	ENERGY SPENT ON LOST MATERIAL Kwh/T paper
Cellulosic fines	6,500/—	65	220	1430/—	16,5
Fillers	2,200/—	55	80	176/—	0.13
Rosin	30,000/—	35	6.5	195/—	0.065
Alum	1,80o/—	45	38.5	68/5	0.33

Approximately 70 to 80 Kg of filler is lost during sheet formation when 22% on oven dry pulp is added to maintain the paper ash content of 15%. The cost of filler going into the system is around Rs. 176/—. The presence of filler is very harmful for the approach flow circuit as it erodes, corrodes the equipments, forms very hard scales with alum and rosin, and hinders the fiber recovery in flotation or filtration type savealls.

The Indian paper industry is using solid or liquid alum. Some of the mills are also using Poly Aluminum Chloride costing around Rs. 2300/- per ton. PAC is good and performs better than alum in controlling the Electrokinetic Potential of the furnish provided it is used carefully. Being a polymer and having free HCl the pH and sizing requirements need to be studied for every furnish or system before the use of PAC. Alum is safe from process control aspects. General consumption levels of alum are around 5-7%. Alum in recycled water is not wasted. With 7% consumption, the cost value of the material recirculated is Rs 68.50.

The fibers, fines and cellulosic constituents lost in first pass retention are much, 220 Kg per ton of paper produced. The value of the material is Rs. 1430/- (Refer Table-II).

Cost of Energy Lost With the Draining Constituents

The average power consumed on pulp fiber for stock preparation is 200 Kwh per Ton of paper produced. The cellulosic component lost through the forming fabric contains mostly fines, and very little fibers. The value of energy lost is 16.5 Kwh per Ton of paper prduced (See Table-II.)

Accounting for the amount of energy required in agitators, pumps, the net energy used in preparation of slurry from 1 Ton of dry filler is around 1 8 Kwh, and 0.13 Kwh per Ton of paper produced equivalent filler drains through fabric.

Rosin emulsion preparation requires two forms of energy, the steam and the power. The electrical energy used is very little only 0.1 Kwh per Ton of dry rosin. However the steam requirement is 0.44 Ton (Low Pressure 3.5 Kg/cm^2 steam), which is equivalent to 11.1 Kwh per ton dry rosin. The value of net energy lost through drained rosin cotent will come out to be 0.065 Kwh per Ton of paper produced.

Alum on the same scale need approximately 8.6 Kwh per Ton of dry brick alum dissolved and on the basis of first pass retention, the amount of energy lost by drained alum is 0.33 Kwh per Ton of Paper Produced

Savings with 10% Improvement in First Pass Retention

The FPR level can be conveniently improved to 75% by better process control. By achieving 10% beter FPR, i.e. attaining a level of 71.5% the saving in terms of rupee value and power is worth Rs. 186.95

and I.70 Kwh per Ton of paper. To achieve these levels of first pass retention, good process controls is necessary.

Recently, the control of papermaking systems through the electro kinetic charge or potential is gaining significance. The development of on line potential control and their increased use in western paper industries is an indication of the reliability of zeta potential as process control parameter. The concept of zeta potential, streaming potential has been brought in mainly by the increasing use of polymers as retention aids. To understand the role of any retention aid or to select proper retention aid, the charge or potential level of furnish plays a very decisive function. The retention aids are mainly required to agglomerate or flocculate the fiber, fines or to provide bridging mechanism among the fines to increase their apparent specific size/volume so that they are retained on the web.

The level of furnish charge or potential also indicate the amount of repulsive forces acting among various constituents in headbox or over fabric. Greater is the amount of repulsive force, higher will be the probability of fines being removed by the external forces like vacuum created by the fourdrinier wire table components. For best retention levels, the potential of the furnish should be near zero.

Papermaking furnish has particles of microscopic size to colloidal size. The particles of very small to colloidal size are mainly lost during paper formation stage. The application of zeta potential in papermaking systems was therefore studied and the results of the studies are presented.

Application Of Zeta Potential Measurement Technique To Investigate Retention In Paper Making.

Zeta potential of a colloidal suspension is a valuable parameter and provide a convenient way of judging its electrokinetic behavior. By manipulating it, desired flocculation characteristics in a suspension can be achieved. If two system of different zeta potential are compared with all other parameters being equal, the one that has a higher zeta potential is expected to be more stable with respect to flocculation than one with lower zeta potential. Thus zeta potential measurement can be used as an indicator for optimum condition for flocculation. Fig 1. presents a sketch of how the zeta potential of negatively charged (anionic) particles change during the addition of $Al_2(SO_4)_3$ to the suspension.

The mechanism of controlling the tendency of a colloidal suspension by varying zeta potential has found applications in papermaking. Better retention of fines and additives on fibers can be achieved by bringing the zeta potential close to zero.

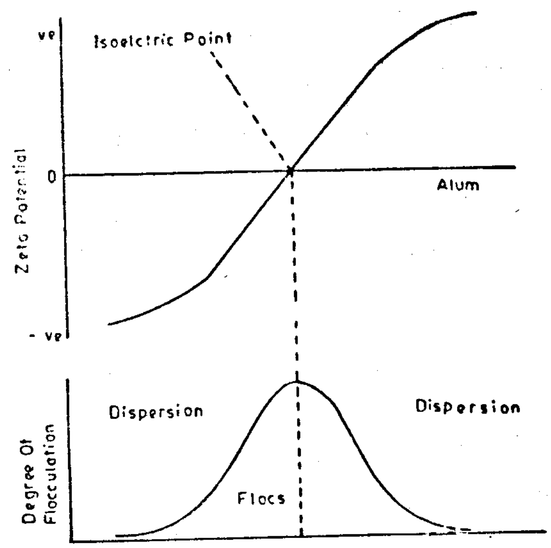

FIG. 1. Effect of Addition of Alum in Paper Furnish on Zeta Potential and Degree of Flocculation.

Cellulose being weakly negative due to absorption of OH^- ions, absorb aluminum ions Al^{3+} from alum, and become less negative. The zeta potential decreases, causing a corresponding increase in flocculating tendency. The maximum flocculation is reached at the isoelectric point. By further adding alum, charge reversal takes place and zeta potential starts increasing in positive direction and a stable dispersion may again be achieved.

Thus the object of binding smaller particles to fibers can be achieved by varying the electrokinetic charge and hence zeta potential of paper furnish, which leads to higher retention of fiber fines, and additives in the web.

Pulps Investigated

The pulp samples of individual species were prepared in the laboratory. The most commonly used species for the manufacture of writing printing grades of paper were selected for investigations.

The types of pulps selected for studies were the bleached pulps, Bamboo pulp, Eucalyptus pulp, Straw pulps (wheat and Rice), Bagasse pulp, Typical commercial mix consisting of 70% Eucalyptus, 18%, Bamboo, 12% Pine.

To find the interrelationship between zeta potential and first pass fine retention, paper maker's alum was used in varying quantities to bring step wise change in zeta potential. First pass retention of fines was determined at each level of alum. Mark IV retention jar was used to determine the first pass retention. This relationship was taken as basis for selecting the zeta potential level for maximum retention of fines for pulp.

Pulp Characterization

The experiments were designed to find the level of zeta potential to attain maximum first pass retention for a typical furnish used for manufacture of printing papers The first step was therefore to characterize the pulps by their individual initial zeta potential. Zeta potential of different pulps were :

Pulps	Zeta Potential (mV)
Bamboo	(—) 16.0
Eucalyptus	(—) 14.8
Straws	(—) 19.4
Bagasse	(—) 17.9
Commercial	(--) 12.6

The bleached pulp samples have zeta potential in the range of (—) 12 mV to (—) 19 mV. The amount of carboxyl content in the pulp is a major constituent contributing to zeta potential of the pulp.

The commercial mix has lower zeta potential value than the laboratory prepared pulp samples. The reason my be the use of ground and untreated hard water.

Agriresidue pulps like straws and bagasse have relatively lower zeta potential, the reasons for which can be :

(i) Higher ionization of polar groups present in pulps due to their lower degree of polymerization.

(ii) More absorption of hydroxyl ions from water, as the agriresidue pulps are invariably more hydrated than wood pulps.

(iii) The crystal lattice of cellulose in the agriresidue pulps is less, and apparently undergoes partial dissolution.

Furnish Composition

The furnish composition selected for investigations was with 1% rosin, 1% starch, 10% filler and alum as per requirements. The sequence identified for investigations were :-

Starch — Rosin — Alum — Filler

Starch — Rosin — Filler — Alum

Rosin — Starch — Filler — Alum

The basis for the selection of the three sequences was some of the general principles adopted while deciding the sequence of additives in practice.

Once the best zeta potential value for maximum first pass retention of refined pulp was identified, following was done :

(1) Chemical additives were added in different sequence. The first pass retention values were determined for different sequence. The sequence giving maximum first pass retenaion was considered best for particular grade of pulp.

(2) The effect of varying dose of alum was studied with each sequence to find the best zeta potential and alum dosing level for maximum first pass retention.

Zeta Potential Levels For Maximum Retention

With the addition of alum, Zeta potential of pulp was found to approach zero zeta potential value with corresponding increase in first pass retention value.

Maximum first pass retention did not necessarily appear at zero zeta potential. For various pulps, the value of maximum first pass retention occurred at different zeta potential.

Pulp sample	Zeta potential for Max. First pass retention	Alum %	Ref. Fig.
Bamboo	(–)3mv to O	2.6	2
Eucalyptus	0 to +3 mv	2.3	
Straws	(-) 2 mv to 0	2.4	
Bagasse	(–) 5 mv	2.1	3
Commercial mix	(+) 3 to (+)8mV	1.9	

The electrokinetic approach for maximum retention is to balance the charge of the system towards near zero zeta potential at which maximum retention is obtained.

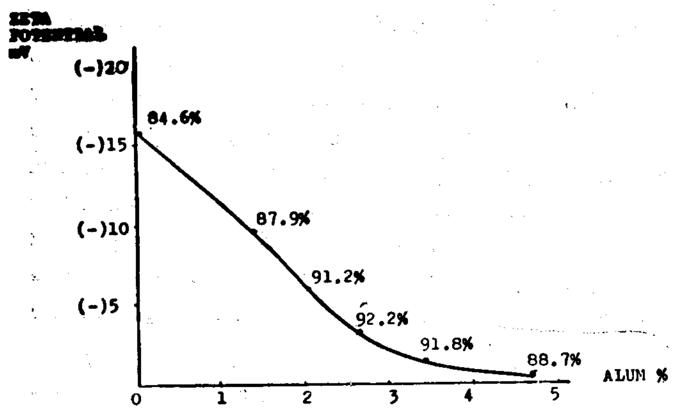

FIG. 2. ZETA POTENTIAL AND ALUM DOSING RELATIONSHIP FOR BAMBOO PULP WITH FIRST PASS RETENTION ON MARK IV JAR.

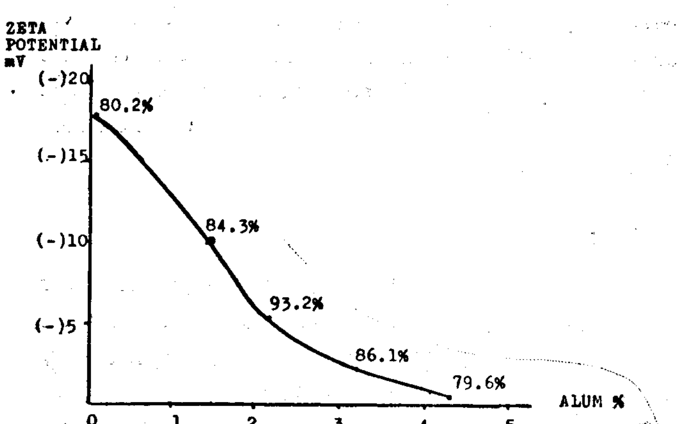

FIG. 3. ZETA POTENTIAL AND ALUM DOSING RELATIONSHIP FOR BAGASSE PULP WITH FIRST PASS RETENTION ON MARK IV JAR.

Paper Properties and retention relationship :

The standard sheets of furnish experimented were prepared on the dynamic sheet mold. These sheets were tested for their common strength, body and optical properties. The gain in retention affected the properties of the sheets. The retention of fines and chemicals showed effect on following properties of laboratory sheets :-

(i) Tensile strength showed a marginal increase. (3 % to 5%)

(ii) Elongation of sheets was also found to slightly more. The net gain was in TEA gain.

(iii) Tearing strength remained unchanged. Although there could be a possible fall in its value.

(iv) Appreciable gain in optical properties like scattering coefficient and opacity was observed

(v) The density of sheet also showed a positive gain.

Conclusions From Retention Experiments

The experimental results on laboratory and commercial pulp lead to the inference that the zeta potential of pulp suspension is dependent on chemical properties of fibers and amount and nature of additives in furnish.

The results could lead to few generalized conclusions :—

(i) Zeta potential of furnish is affected by those additives which have some affinity to pulp fibers. The independent additives like filler particles do not change zeta potential of furnish inspite of their relatively higher quantity (10%) against very small (1%) dosing level of starch and rosin on dry fibers.

(ii) Zeta potential control of furnish is a purposeful tool to achieve higher retention. The zeta potential value has to be nearer to zero to avoid any repulsive force among particles. The actual levels of zeta potential obtained for various pulps for maximum first pass was recorded on a dynamic retention jar simulating actual turbulence on machine.

Since the experiments were carried out in laboratory, following were the limitations :-

(i) The amount and nature of chemical additives was predecided.

(ii) There was no recirculation of water. Thus, the effects of residual free acidity, dissolved chemicals in drained water and recycling of fines could not be studied.