The Use of Polysaccharide Derivatives for Better Yields in Paper Manufacture

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SUMMARY

The mechanism for a higher retention of fillers and fibre fines by the addition of low levels of polysaccharide derivatives is discussed. This results in higher yields of paper and higher production rates.

The mechanism consists of flocculation of fillers and fines through a bridging action by the polysaccharide derivative chains and the neutralization of surface charges which also facilitates filtration on the paper machine. The bridging action is a function of the molecular weight whereas the neutralization depends on the charge of the polysaccharide derivative. A series of such derivatives have been tailored to match the above properties and have potential for use by the paper mills for higher levels and rates of paper production.

Additional advantages are, increased dry strengths of paper sheets, ease of recycling of paper and the reduction of pollution problems in paper mills.

INTRODUCTION

In the context of the Indian situation with a rapidly increasing demand for paper, it is of paramount importance to increase the production of paper as well as to increase the productivity within the existing paper mills.

The production can be increased by two ways:

(1) Increased usage of fibrous substrates such as hardwoods, bamboo and straw.

(2) Usage of speciality chemicals which are added as wet-end additives. These result in higher production levels by an increased retention of fillers and fines and increased productivity in existing plants by higher production rates on the paper machine.

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The objective of this paper is to highlight the use of speciality chemicals as wet-end additives for more paper production and higher productivity.

MECHANISM FOR HIGHER RETENTION OF FILLERS AND FINES

The mechanism is one of flocculation. Flocculation is a progress by which smaller particles of fillers and fibre fines are brought together to form larger particles with a higher porosity. The initial fine particles are filtered at a slow rate. However, by the process of flocculation, larger particles called "flocs" are produced and can be filtered rapidly and can settle rapidly on the paper sheet being formed. The final structure of a floc is a loose three-dimensional network, resulting a bridging action of macromolecular flocculants between the fine particles. Polymeric flocculants have been employed on a rapidly expanding scale by the paper industry. Since polymers derived from petrochemical sources are becoming costlier i.e. $ 4—7/Kg, there is a definite need for tailoring polysaccharides as flocculants/filtration aids and for pollution control for the paper industry. The raw polysaccharides are generally available at a price below \$1/Kg.

Flocculation involves the adsorption of a polymer on to surfaces of solid particles. This can be approximated by a simple adsorption isotherm of the Langmuir type i.e.

$$\frac{\theta}{1-\theta} = bP$$

where P = equilibrium concentration of polymer in solution, "b" is the adsorption constant depending on the polymer—particle interaction, and θ = fraction of adsorption sites on the surface of the solid particles covered by the adsorbed polymer P. P is in turn related to the initial polymer concentration P_o.

$$P = P_o - kw\theta$$

where w = solids content of the suspension and k = constant depending upon the specific area of the solid and the number of adsorption sites per unit area.

Combining the above two equations yeild

$$\theta = \frac{b\,(P_o - kw\theta)}{1 + b\,(P_o - kw\theta)}$$

As P_o increases, θ also increases; and as w decreases, θ again increases.

The polymer molecules attached to solid particles have additional sites on which additional solid particles can be attached and this would then lead to flocculation by a bridging mechanism so that a macromolecular network is formed with the solid particles bound by the polymers. This network has a three-dimensional structure. The bridging mechanism is a bimolecular process, the rate of which is dependent upon the concentration of the particles carrying the flocculant, $N_o \cdot \theta$ (where N_o = number of particles per unit volume) and also on the concentration of particles with free surface able to adsorb the flocculant $N_o\ (1-\theta)$. The rate of formation of the floc can be given by

$$\frac{dn_o}{dt} = k_1\ N_o^2\theta\ (1-\theta) \text{ where } k_1$$

is a constant. The rate of breakdown of the floc is given by :

$$\frac{dn_o}{dt} = -\frac{k_2R}{\theta(1-\theta)}$$

where k_2 = constant, R = radius of the flock and $\theta(1-\theta)$ is the bridging factor.

Thus the rate of breakdown of flock is proportional to the volume of the floc and inversely proportional to the surface area and to the bridging factor, $\theta(1-\theta)$. Bridges can conceivably be formed by a physical entanglement or hydrogen bonding between extended segments of chains.

Since the size of the floc is a function of the extension of the polymer chain which is in turn very high for high molecular weight polymers, there is scope for development of flocculants based on polysaccharides for fibre fines and fillers.

Another important aspect is the charge on the polysaccharide chain. Charged chains can neutralize the charge on the paper fibre fines and fillers, resulting in more efficient flocculation. The cellulosic fibre fines are generally anionic in nature and are easily flocculated by cationic polysaccharides or by anionic polysaccharides (with the addition of metallic ions such as Al^{3+} in the form of alum).

Hence charged polysaccharides are ideal for increasing retention of cellulosic fines and these also result in a better retention of fillers. An increased filler content in a paper sheet would normally reduce its strength properties. But with charged polysaccharide derivaties, increased strengths of the finished paper sheets are obtained due to a stronger inter-fibre bonding, despite increased filler contents. This also means low production costs for paper.

RESULTS

Our findings are that strengths of handsheets can be increased several fold by adding small quantities of wet-end additives i.e. 0.5 to 1.5% (based on oven-dry pulp) (See Table 1).

Our results indicate that for the same fibre, the burst factor goes up by a factor of 1.5, the tensile strength by a factor of 2, tear strength by a factor of 1.5, and folding endurance several times i.e. by a factor of 10.

The samples WEA—1 to 4 also help in reducing the energy required during the beating process. The effect of the additives on the retention of fillers and fines has yet to be studied.

TABLE - 1 RESULTS OF EXPERIMENTS ON WET END ADDITIVES

TESTS		BLANK	WEA—1			WEA - 2			WEA—3			WEA—4		
			0.5%	1%	1.5%	0.5%	1%	1.5%	0.5%	1%	1.5%	0.5%	1%	1.5%
Substance, G.S.M	Max.	201	229	157	143	189	183	145	186	219	202	245	148	148
	Min.	76	83	90	77	66	91	88	71	125	102	71	99	87
	Avg.	110	140	124	121	124	121	108	145	152	143	169	117	130
No. of test		8	10	10	10	10	10	9	10	10	10	12	11	10
Burst Facter	Max.	22	18.7	22.9	28.0	29.4	36.3	32.6	30.9	28.5	35.9	35.5	30.4	30.3
	Min.	13	13.1	17.2	25.8	18.8	27.2	25.5	22.8	22.3	23.4	14.0	25.2	25.0
	Avg.	17.2	15.3	20.6	26.9	24.7	31.9	29.2	27.7	26.0	29.8	22.0	28.4	29.2
No. of test		4	5	5	5	6	5	4	5	5	5	7	6	5
Tensile Breaking Length in Metres	Max.	2300	2200	2850	3140	3290	3930	4550	3630	3560	3680	3810	4260	3290
	Min.	390	630	710	2160	560	2360	1600	1970	2000	2610	1880	2990	920
	Avg.	1300	1700	2150	2660	2260	3420	3030	2810	2860	3270	2950	3480	2650
No. of test		8	8	8	10	10	10	9	10	10	10	10	11	10
Folding Endurance	Max.	54	164	159	631	674	722	564	932	678	626	1100	463	749
	Min.	17	23	46	75	28	120	89	35	105	43	177	57	128
	Avg.	31	84	87	264	209	442	326	520	302	329	460	226	438
No. of test		8	9	9	10	10	9	9	10	10	10	11	11	10
Tear factor	Max.	165.0	130.0	146.4	157.1	128.0	263.7	209.6	138.1	247.1	177.7	143.7	107.0	251.4
	Min.	78.0	98.7	121.9	133.3	93.5	105.5	134.4	98.4	119.1	114.8	115.0	87.2	133.3
	Avg.	124.0	107.7	137.5	139.4	114.7	170.1	172.3	118.9	192.1	153.9	129.9	91.1	219.5
No. of test		4	4	4	5	4	5	5	5	5	5	5	5	5
°SR		32	37	39	55	40	47	51	68	40	42	47	52	55

CONCLUSION

Superior strength properties have been obtained by the addition of small quantities of wet-end additives that are likely to offset any decrease in properties that might otherwise result as a consequence of and increased filler content in the paper sheet.

The increased retention of fillers and fibre fines is likely to result from the flocculation by polysaccharide chains in accordance with the mechanism discussed in this paper.

REFERENCES

(1) "Outlines of Chemical Technology" edited by M. Gopala Rao and Marshall Sitting, Affiliated East-West Press Ltd., New Delhi/Madras, 2nd Edition, 1973.