Significance of high brightness in paper from Agro residues pulp and its impact on environment

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ABSTRACT

Agro residue pulp is an important raw material for Indian paper industry. To get maximum paper making potential from such pulp there is a need to avoid excessive degradation due to over bleaching in attaining high brightness which is considered as only important optical parameter in paper trading. Visually a user assesses the paper quality not only by brightness alone but the components namely brightness, whiteness and dirt count are taken together. In agro residue pulp higher brightness more than 80 % has shown adverse effect on fibre strength which got dropped by 31%, tearing strength dropped by 27 % and print through increased by 43 %. Stronger paper with better print quality can be made if brightness is restricted to 80 % ISO brightness, however along with it CIE whiteness W C/2 of 100 % and dirt count below 20 mm^2/m^2 are also be included as quality parameters. These parameters will keep good visual appearance of paper inspite of low brightness. The steps of avoiding over bleaching to get high brightness will also save the environment from pollution due to restricted use of oxidative/ reductive bleaching chemicals and undue excessive generation of pollutants.

Keywords: agro residue pulp, brightness, whiteness, dirt count, print through, fibre strength.

Introduction

Paper industry in India is highly fragmented industry. This can broadly be categorised into three segments namely wood, agro residue and waste paper based. Presently the production scenario of paper is 32 % from agro residue pulp, 38 % from recycled waste paper fibres and remaining 30 % from wood/bamboo pulps. Agro residues like wheat straw, rice straw, bagasse, sarkanda and other straws are being used by Indian paper industry to protect the forest resources helping eco-friendly environment. The latest trend in Indian paper industry is to attain high brightness level around +90 % ISO brightness in tune with the trend prevalent in Europe where only wood is used as raw material. Brightness may not add much value to the useful properties of paper, but it is most important selling feature. There is a need to analyse whether such brightness level is really suitable for Agro based paper as these paper fibres are having low inherent intrinsic fibre strength. Fibre strength of pulp is inherent characteristic and strength properties of paper are mainly dependent on it. The fibre strength of Agro pulps is normally 6 to 8 km. and waste paper is 9 to10 km. as compared to 16 to 20 km. for wood fibres. In addition, after achieving reasonably good level around 80 % level of brightness, expensive oxidative/reductive chemicals are used which lead to increase in pollution load and production cost. The presence of excessive primary fines more than 30 percent in Agro pulps is another negative factor from paper making point of view. So it becomes important that serious thoughts are given to avoid excessive degradation of such fibres to get maximum paper making potential from them.

The optical properties of paper are no doubt important as the first impression which one basically receives from a paper is its colour, its whiteness and gloss. The appearance of paper is also important for selling and printing. Presently in Indian paper industry the quality of paper is mainly specified by brightness and opacity as optical parameters. In this paper attempt has been made to include more parameters which can describe paper quality better without extra emphasize on brightness and little impact on end use.

Results & Discussion

Optical properties of paper

Optical properties of paper are influenced by process, materials and additives. Bleaching reduces the light absorption of pulp, and refining of chemical pulp leads to decrease in light scattering. Fillers have an important function in increasing opacity. The refractive index, specific surface area and pore size influence the optical properties of the pigment- filled paper sheet. Dyes and fluorescent whitening agent are important additives which influence the optical properties of paper. In a paper sheet diffuse

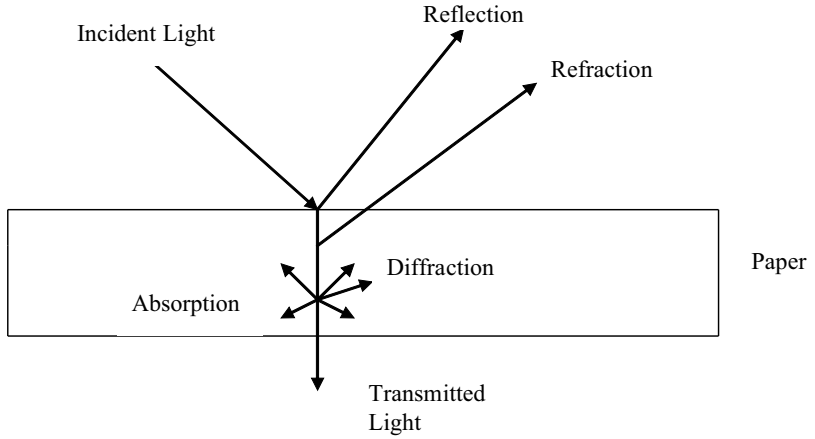

Fig.1- Generalized behavior of light striking the paper surface

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reflection, refraction, diffraction and absorption of light take place as illustrated in Fig.1. Paper is a complex structure of fibers, fillers and air. Light is reflected at fiber and pigment surfaces in the surface layer and inside the paper structure. The light also penetrates into the fibers and pigment and changes direction. Some light is absorbed but the remainder passes into the air and is reflected and refracted again by new fibers and pigments and changes direction. After number of reflections and refractions, a certain proportion of light reaches the paper surface again and is reflected at all possible angles from the surface. Some of the incident light exits at the back of the paper as transmitted light and the remainder gets absorbed by the cellulose and the pigments. Besides reflection, refraction and absorption there is a fourth effect called diffraction. Diffraction occurs when the light meets particles or pores which are smaller than the wavelength of light i.e. particles which are smaller than one micrometer (μm). These small elements oscillate with light oscillation and thus function as sites for new light sources. When the particles or pores are smaller than half the wavelength of the light the diffraction decreases. It can be said that the light passes around the particles without being affected.

Table - 1
Distribution of chemical component in fiber matrix of paper making raw material (Ref.1)

Wall Layer	Lignin (%)	Cellulose (%)	Hemicellulose (%)
Middle lamella	90	0	10
Primary Wall	70	10	20
Secondary Wall S1	40	35	25
Secondary Wall S2	15	55	30
Secondary Wall S3	10	55	35

Table - 2
Chemical treatments generally used in bleaching of paper making fiber

Bleaching Stage	Symbol	Comments about treatment
Treatment with acid	A	
Chlorine	C	Not very selective, carbohydrate degradation also occur.
Chlorine dioxide	D	Expensive but selective.
Alkali extraction	E	Remove fragmented lignin
Hypochlorite	H	More selective than elemental chlorine
Oxygen	O	Least selective for lignin, cheapest to use
Hydrogen peroxide	P	Highly corrosive becomes more common with elimination of chlorine
Chelating Stage	Q	
Per acetic Stage	T	
Enzyme Stage	X	
Diothionite	Y	
Ozone	Z	

Making bleached pulp for paper manufacture-

For paper making, cellulose fibres are extracted from fibrous raw material which are generally wood or non wood. The fibrous raw material mainly contains fibers with region of middle lamella between them. Middle lamella consists mainly of lignin. The fibers consist of mainly three types of material namely- cellulose, hemicellulose and lignin, fibres have layered walled structure namely primary layer (P) and secondary layers (S_1, S_2, S_3). The general distribution of cellulose, hemicellulose and lignin in a fiber matrix indicate that useful paper making fibers are after secondary S1 wall layer which contains, high percentage of cellulose, hemicellulose and some lignin (Table 1). Cellulose and hemicellulose are only important components for the paper manufacture.

To make chemical bleached pulp different chemicals are used to remove maximum amount of lignin. In pulping, the middle lamella gets dissolved and S1 layer is also affected. The remaining lignin gets removed during bleaching stages. In bleaching main objective is to remove lignin from other secondary layers S2, S3 with least degradation of cellulose. This removal is rather more difficult in the case of non woody fibers as such fibers have relatively more number of secondary layers than woody material. Any attempt to get higher brightness for such fibers will give relatively more adverse effect on the fiber strength, thus relatively poor strength in paper.

Bleaching of chemical pulps is usually a multi stage process where the lignin is oxidized, decomposed and finally eliminated from pulp fiber. This results in less chromophores in the pulp. Bleaching is usually carried out in stepwise sequence, utilizing different chemicals and conditions in each stage. The generally used chemical treatments are listed in Table 2.

In India, the bleaching sequence employed for agro residue pulps is mainly CEHH and few mills have adopted DEPD sequence. The chances of degradation are more in the case of CEHH sequence. For such pulps which are weak in nature any attempts to increase the brightness after certain level will cause excessive fiber strength detoriation.

Deterioration effect of Agro pulp fibers on paper quality in comparison to other raw material

Table - 3
Number of fibers piled up on top of one another for different raw material in a 60 grammage paper sheet

Raw material	Fibre width (μ)	Coarseness (μg/m)	No. of piled up fibre
Straw	12-14	70-80	10-11
Bagasse	18-23	110-120	10-12
Eucalyptus	13-17	120-130	7-8
Bamboo	15-18	140-160	6-7
Softwood	25-36	320-360	5-6

Table - 4
Optical characteristics of different white printing samples made from agro residue pulp

Sample No.	Brightness % ISO	Whiteness W C/2	Dirt count (mm^2/m^2)	Rank Number	Sample No	Brightness % ISO	Whiteness W C/2	Dirt count (mm^2/m^2)	Rank Number
1	80.2	100.9	2	3	**24**	81.7	102.5	5	4
2	77.1	79.78	6	14	**25**	79.9	104.6	37	4
3	79.3	100.2	36	12	**26**	80.6	105.7	29	7
4	80.1	101.2	3	2	**27**	81.5	104.5	10	2
5	74.2	75.3	5	17	**28**	81.9	109.8	5	1
6	84.5	91.1	5	12	**29**	76.2	99.7	15	11
7	73.8	94.0	6	11	**30**	79.8	105.6	1	4
8	72.7	87.0	4	12	**31**	71.4	103.4	331	23
9	74.2	92.0	16	13	**32**	68.9	97.1	259	24
10	74.1	92.0	3	8	**33**	73.3	95.2	148	20
11	82.4	101.2	5	2	**34**	74.7	98.7	92	19
12	82.7	102.9	6	3	**35**	80.1	102.8	14	7
13	73.0	78.9	7	18	**36**	84.5	92.9	7	15
14	73.9	78.4	1	14	**37**	76.9	83.1	9	16
15	73.1	99.4	156	22	**38**	73.2	103.4	28	12
16	68.7	79.2	31	23	**39**	84.7	105.4	9	1
17	74.5	94.3	23	19	**40**	76.9	112.1	31	10
18	78.1	94.0	0	7	**41**	73.0	87.8	170	22
19	80.1	100.8	0	6	**42**	73.4	92.2	240	21
20	80.2	101.9	1	5	**43**	74.1	98.2	21	16
21	75.6	87.0	179	20	**44**	78.7	102.2	77	13
22	77.7	107.5	94	14	**45**	77.7	102.9	18	9
23	70.3	85.9	33	22					

Paper is a generally pseudo-random array of fibers. It is an extremely thin material, containing in excess of a million fibers per gram. The average number of fibers piled on top of one another at a given point can be approximately be calculated using follows expression -

Number of fibres = [grammage (g/m^2)*fiber width (μ)]/coarseness (μg/m)

The numbers of fiber as calculated which will pile up on one above the other for 60 g/m^2 sheet for different raw material are given in Table 3. Quite clearly for straw pulp 10 to 12 fibers will be there as compared to 7 to 8 for eucalyptus, 6 to 7 for bamboo and 5 to 6 for softwood pulp. This implies that any deterioration in fibers from agro pulp will show about double negative effect on paper properties as compared to wood pulp. However, large number of fibers in straw will be helpful in getting more scattering of light so even low level of brightness will apparently look reasonably good for such pulps.

Commonly used optical parameters of paper as specification of paper quality

Optical parameters commonly used in specifying paper qualities are brightness, opacity, whiteness, dirt content. The definitions of these are as under-

Brightness:

Brightness is the intrinsic reflectance factor measured with the reflactometer equipped with a filter or corresponding function having an effective wavelength of 457 nm and a width at half height of 44 nm, and a just so that the UV content of illumination incident upon the test piece corresponds to that of the CIE illuminant C.

Opacity:

The ratio expressed as a percentage of single sheet luminous reflectance factor R_0 to the intrinsic luminous reflectance factor $R\infty$ of the same sample.

Whiteness:

It is a combination of the total reflectance of white light and uniformity of the reflectance at all wavelengths. CIE whiteness is whiteness derived from CIE tristimulus values.

Dirt content:

Dirt in paper or paper board is defined as any foreign matter embedded in the sheet, which, when examined by reflected, not transmitted, light has a contrasting color to the rest of the surface and has equivalent black area of 0.04 mm^2 or over.

The equivalent black area of direct specks is defined as the area of a dirt speck is defined as the area of a round black spot on the white background.

Paper as the observer sees it

In order to assess the parameters which

an observer sees, paper experts were asked to give rank number to samples on the basis of visual appearance. It was seen that all the observers were grading the samples by taking the properties brightness, whiteness and presence of dirt and specks altogether not on basis of brightness alone. The data on optical characteristics of different commercial white printing paper samples manufactured from agro residues pulp collected from Indian market is recorded in the Table 4. It was observed that paper experts are looking brightness, whiteness and dirt count all together and assigning the rank number. Paper sample with higher whiteness, low dirt count at the same level of brightness was given low rank number i.e. that is preference in quality. This indicated that instead of specifying only brightness, whiteness and dirt count needs also to be included on quality parameters. Paper having minimum 80 % ISO brightness 100 % CIE W C/2 whiteness and dirt level below 20 mm^2/m^2 for printing paper could be sufficient instead of specifying high brightness value more than 80 % only. Samples with higher brightness than 80 % but having lower whiteness than 100 % were given higher rank number i.e. visually low quality.

Effect of brightness on properties of paper made from agro residues

In order to access the effect of high brightness on strength and printing characteristics of paper, agro residue pulp containing wheat straw and sarkanda having 80 % and 85 % brightness collected from a paper mill were examined in detail. Handsheets were prepared under same degree of sizing and level of whiteness. The sheets were examined for strength, printing and optical characteristics (Table 5). The results indicate that attaining high brightness is causing negative effect on Specific scattering co-efficient, fiber strength, tear index and print through from paper making aspect, high light scattering is good since paper then becomes more opaque and whiter. The print density and tensile index are not improved with high brightness clearly high brightness in case of agro residue pulp is not helping in improvement in printing quality but giving adverse effect on fiber strength which got dropped by 31 %, tear index dropped by 27 % and print through increased by 43 %.

Conclusions

Specifying paper quality by brightness alone as optical characteristics is not be suffice as visually an observer is judging paper quality by three optical parameters brightness, whiteness and dirt count taken together. Attaining high brightness after 80 % in case of agro residue pulp which inherently have low fiber strength should be avoided as this leads to drop in fiber strength by 31%, tearing strength by 27 % and increase in print through by 43 %. Paper with 80 % ISO brightness, 100 % CIE W C/2 whiteness and dirt level below 20 mm^2/m^2 will have good visual appearance and better strength and printing properties than paper with high brightness alone.

Experimental

All the tests were carried out according to relevant ISO Standards. The printing tests were carried out after printing the paper using IGT printability tester (Model AIC2-5).

References

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3. "*Determination of opacity (paper packing) - Diffuse reflectance method"'* ISO 2471
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5. *"Dirt in Paper and Paper Board"* (Tappi Press)

Table - 5
Effect of high brightness on 60 grammage paper made from agro residue pulp

Parameter	Values obtained	
	Pulp 1	**Pulp 2**
Brightness (%ISO)	80.0	85.0
Whiteness (%)	112.5	112.5
Scattering Co-efficient (m^2/kg)	38.5	35.5
Opacity (%)	90.1	87.5
Tensile Index (N.m/g)	52.5	52.0
Tear Index ($mN.m^2/g$)	5.50	4.00
Fiber Strength Index (km)	7.5	5.2
Ink layer for 0.9 print density (μ)	7.5	7.5
Print Through (macbeth)	0.35	0.50