A Practical Approach For Eradication Of Fluff Problem In Paper Industry: Causes And Remedies

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ABSTRACT

In South Asian countries, most of the paper manufacturers and printers are facing the problem of fluff generation during paper manufacturing and paper printing which results in poor machine runnability, production loss, increased ink consumption and reduction in the print impression per hour. Aiming this, anatomical, morphological and chemical characterizations of common hardwoods and agro-based residues with respect to fluff generation were summarized. The mechanism of press picking during printing was also discussed. The various paper machine process parameters and use of bio-chemical methods to mitigate fluff generation due to vessels and parenchymatous cells were discussed.

INTRODUCTION

World demand for paper has increased at an average annual rate of 4.7% over the past 40 years. Although future growth will reduce to 2-3% as the existing wood resources may be inadequate to meet this growing demand for paper especially in the Asia-Pacific region and Eastern Europe[1]. World demand for paper and paperboard is likely to grow by 2.1% annually in the long run, reaching an estimated 490 million tons by the year 2020, according to a recent paper demand and supply study[2]. Demand for paper in India is projected to grow at a compounded annual growth rate of 6.10% from 2004-05 to an estimated 7.4 million tons in 2008-09[3]. Forest cover in India is reported to be 67.8 million ha, or 20.6% of the country's surface area, which translates into a per capita forest area of only 0.8 ha/person, one of the lowest in the world[4]. The country's fuel wood requirement alone is 280 million tons/yr, and this will rise to 356 million tons/yr by 2010[5]. Total fiber consumption for the production of paper and paperboard in India will nearly be doubled between 2006 and 2016, growing from 7.4 million tones/yr to 13.7 million tones/yr. India's total wood fiber deficit as per forecast is to increase at an 11.3% annual rate by 2016[4]. The shortage of wood fibers compel the paper industry to use other alternate fiber resources like, non-wood fibers, agro-based residues and waste papers. The scarcity of woody raw materials compels the paper manufacturers to procure immature woody raw materials. This leads to various paper manufacturing problems in which linting or fluffing or press picking problem is of prime importance.

Literature survey indicates that higher lead dryer temperature may cause linting of paper[6]. Fluff is also observed due to the presence of excessive short fibred stock in the paper making furnish. Poor bonding of fibers may also cause lint of paper[7]. High white water pH may cause press picking. Increased solid content either by reducing the jordanning in order to free up the stock if possible or by slowing down machine speed reduces the fluff of paper[8]. High ash content will contribute to fuzz. A dirty felt, dryer rolls might also cause fluff. It is necessary to locate and remove build-up[9]. Deposition and fluff in the dryer section of paper machine has a significant effect on runnability, quality, production rate, cost and safety[10]. Deposition may occur in the form of thin and invisible film on dryer cylinders that causes\ sheet picking, fiber rising and fluffing where as visible deposits on dryer cylinders act as a thermal insulator which adversely affects the heat transfer process and impair moisture removal which in turn will result in reduced productivity and uneven moisture profile[11]. New techniques of surface consolidation, introducing the specialty chemicals both in wet end and size press are of interest in reducing fluffing, although excess consolidation can make fluffing worse. Even low amounts of surface size can produce a very large reduction in fluff[12]. A dirty dryer roll may also cause fluff. It is necessary to locate and remove the build-up[13, 14]. Variations in fiber supply and fiber quality and variations in the uniformity of surface may lead to fluff problem[15]. Chemical additives such as starch, retention aids and polymeric bonding agents have been used with varying degree of success[16]. Variations in fiber supply and fiber quality and variations in the uniformity of surface may lead to fluff problem[17,18]. The relative split between upward and downward drainage in the press section was also mentioned as a possible contribution[19]. The pulp fluff propensity index (PFPI) can be reduced by increasing the specific energy consumption in the refining of the mechanical pulp. The fluff-candidate particles can also be post-refined to improve their bonding properties and so reduce fluffing. Pulp quality has a significant effect on fluffing propensity and if not constant, will mask the effect of papermaking factor.

Printers also look at the performance of their sophisticated printing machines with respect to functional requirement in paper, such as

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creasing during printing and high fluff content with basic requirement like shade, smoothness and size etc. The growing demand from printers, and advertisers, can be summarized as lower surface weight for more printing surface per ton of paper, high brightness and opacity, high mechanical strength with good elastic modulus, good dimensional stability and better print quality[19]. The improvement in print quality could be related to lower fluffing propensity[20]. The increased dampening decreases fluffing; in succeeding units, the effect of blanket on fluffing. The true take-off angle governs ink film splitting forces at the paper surface[21]. Cooper suggested that a mixture of cellulase and xylanase could reduce vessel picking by 50 %, by softening the vessels, making them more amenable to mechanical breakdown, and improving bonding within the sheet[22-23]. Fluff in paper creates fluff deposition in the blanket of the printing machine which results in poor printing machine runnability, production loss, increased ink consumption and reduction in the print impression per hour.

REASONS AND REMEDIES FOR FLUFF GENERATION

Anatomy, morphological and chemical characteristics of cellulosic raw materials:

Wood grown in such a place where ground water level recedes below normal, axial parenchyma protrudes into the vessel through pit, due to a pressure difference in vessel and axial parenchymatous cell on each side of a pit membrane. As a result of protrusion of axial parenchyma cell into vessel advances, it assumes the shape of balloon and it ceases the conduction in vessel (Figure 1). During pulping this balloon like structure retards the penetration of cooking liquor into the chips. The disruption of cooking conditions result discoloured and low pulp yield with more screening rejects higher kappa number and consumption of excess of liquor. Abnormal increase in tyloses also may cause problems for the paper makers. During pulping, balloon structures are separated as isolated elements, causing picking problems during offset printing (Microphotographs 2). This problem may be eradicated by treating the wood chips with hot black liquor and balloon like structure burst which facilitates faster penetration of cooking liquor. Presteaming of wood chips also causes shrinkages of balloon like structure. When these balloon like structures present on paper surface lead to fluff generation.

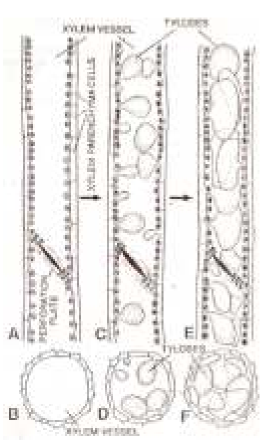


Figure 1: Various developmental of tyloses stges

Microphotographs 2: Radial view of *Eucalyptus camaluensis* showing tyloses

Agro-based raw materials

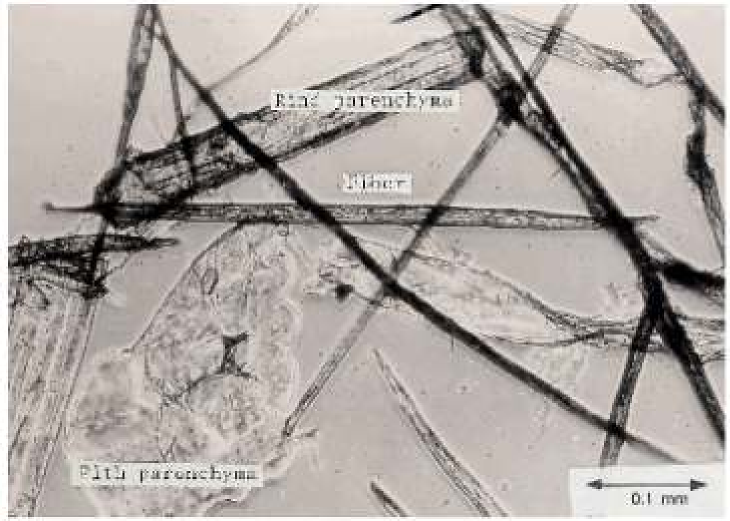
The dimensions of parenchymatous cells of agro-based residues like sugarcane bagasse, wheat straw and rice straw etc. are different; therefore the slot size of screen should be selected according to the morphology of corresponding agro-based residues. The parenchyma and epidermal cells are non-fibrous cells that have large surface area act as fillers (Table1). They adversely affect the mechanical strength properties of paper. Problems in pulping of rice straw are mainly related to breakdown of the dense epidermis. The parenchyma cells of wheat straw are mainly thin walled but quite large held together by a strengthening network, difficult to dissolve. Thus, large flakes of thin walled parenchyma cells can be observed floating in pulp suspension (Microphotographs 3). The thick walled parenchymas are also troublesome residue, difficult to screen mainly because of the cell wall dimensions. The thin walled parenchyma is easily broken down to flexible flakes with some bonding effect while rind parenchyma cells have no bonding effect and are too large to

Table 1: Morphological characteristics of parenchyma cells and vessels of agro-based residues and hardwood

Particulars	Bagasse	Wheat straw	Rice straw	Hard wood
Parenchyma				
Length (µm)	326.9±4.2	450	350	-
Width (µm)	53.4±2.9	130	82	-
%	-	30	-	3-21
Vessels				
Length (µm)	152.3±2.5	100	650	-
Width (µm)	28.1±1.0	60	40	-
%	-	5	-	5-58

A

B



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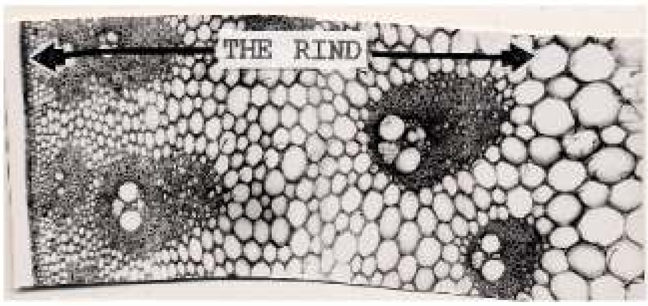

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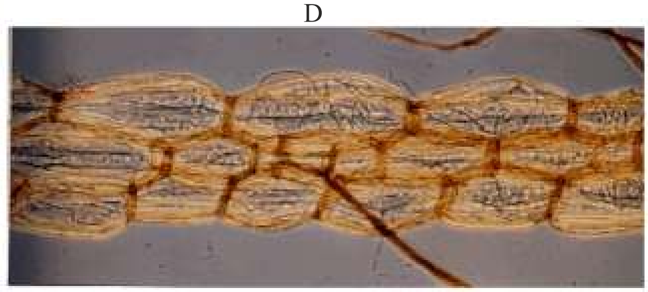

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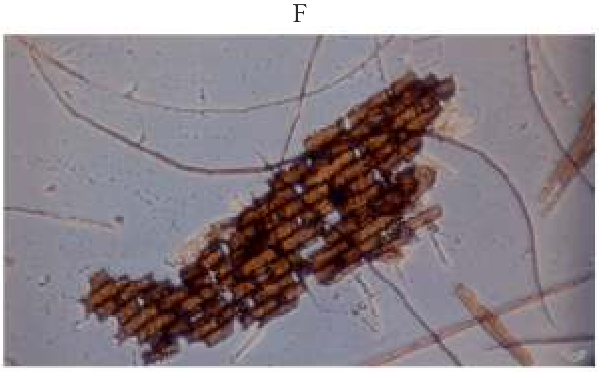


Microphoto graphs 3:(A) SEM of bagasse paper surface showing rind parenchyma (B) Pith and rind cells in bagasse (C) TS of sugarcane bagasse showing rind zone (D) Epidermal cells of wheat straw difficult to dissolve (E) Flakes of epidermal cells difficult to dissolve in wheat straw pulp (F) Undissolved parenchyma cells in wheat straw pulp (G) Big flake of epidermis in rice straw pulp flexible enough to pass the 28 mesh screen (H) SEM of wheat straw paper showing epidermal cells

Courtesy: Laila Hegbom, The University of Trondheim (Norway) function as fillers. When these parenchyma cells present on paper surface lead to linting problem.

Growth factor

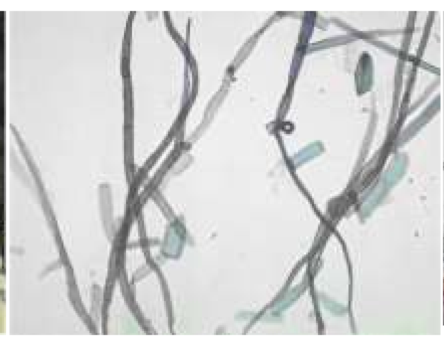
The growth factor also contributes towards fluff generation in dryer section or printing of paper. It is observed that paper manufacturers using *Leucaena leucocephala* face a serious problem of fluff in the drying section of paper machine. *L. leucocephala* of the same species was cut after 2, 3 and 4 years and was analyzed for, morphological, chemical and pulp evaluation characteristics. The fibers of 2 and 3 years old of *L. leucocephala* are immature and consist of more non-fibrous elements i.e. vessels and parenchymatous cells. When such type of fibers are subjected to mechanical attrition, instead of removal of primary wall and fibrillation, more fiber cuttings takes place. The primary wall is permeable to water but does not participate in bond formation. These non-fibrous elements have larger surface area than fibers and their presence affect fiber bonding adversely. The loosely bonded fibers from the paper sheet adhere on press rolls or dryers during sheet making and contribute to fluff problem. *L. leucocephala* cut after 4 years of cultivation does not show fluff problem because of complete cellulose formation of fibers. The results are shown in Table 2 and Microphotographs 4.

Table 2: Bauer McNett fiber classification of fluff samples of *L.* leucocephala and kraft pulp of *L.* leucocephala of age 2, 3, and 4 years

S.NO	Particulars	Fluff fractions, %	Fiber classification of kraft pulp of *L.* leucocephala at 28 °SR of age		
			2 years	3 years	4 years
1	+28	9.24	9.72	18.32	21.42
2	-28+48	52.86	46.46	49.52	53.20
3	-48+100	17.07	12.42	10.62	9.45
4	-100+150	7.46	3.86	5.55	6.12
5	-150	13.37	27.34	15.99	9.18

A

B



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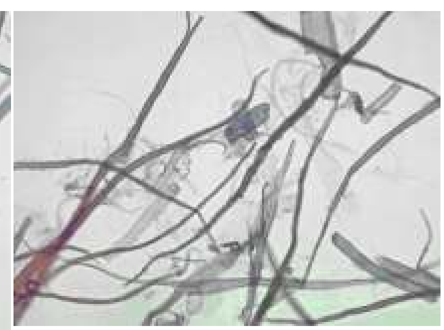
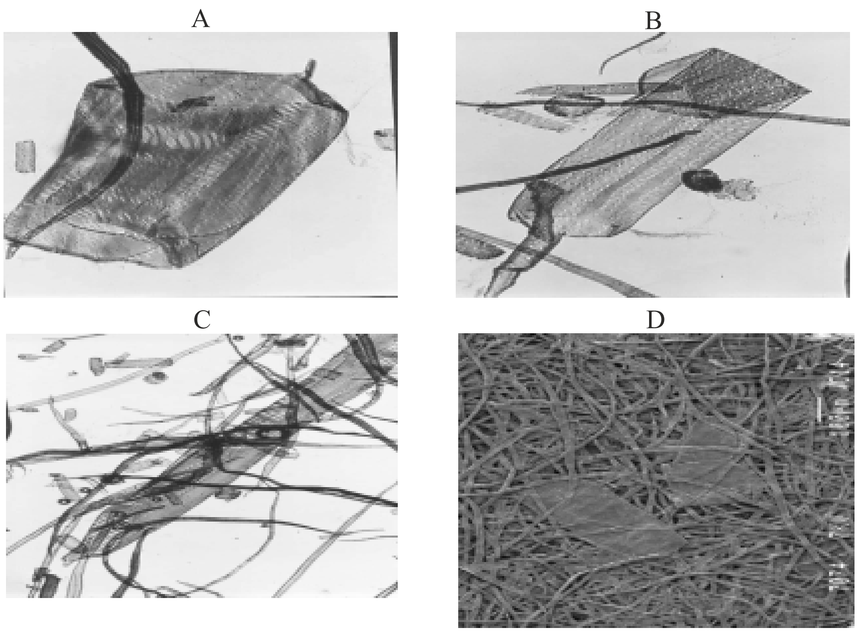


D

Microphotographs 4 (A) Fluff samples (*L. leucocephala* cut after 2 and 3 years of cultivation and pulp blended in the ratio of 1:1) collected from I[st] dryer during paper making shows excess of parenchymatous cells, vessels and broken non-fibrillated short fibers (B) Parenchymatous cells,vessels and complete fibers without fibrillation present in the pulp of L. leucocephala cut after 2 year of cultivation (C) Comparatively less parenchymatous cells and vessels with long and partially fibrillated fibers present in the pulp of L. leucocephalacut after 3 year of cultivation (D) Very few parenchymatous cells and vessels with fibrillated ong fibers present in the pulp of L. leucocephala cut after 4 year of cultivation(Magnification200X)

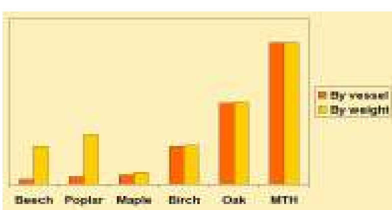
Hardwood vessels picking

Vessels are present in all hardwoods; they are the one of the mechanisms through which the liquids flow through the tree. Size varies enormously between species, Oak and mixed tropical hardwoods have been formed to have vessels of the largest size. Vessels are normally very much wider than the fibers, which may lead to many problems. (Microphotographs 5). The ability of any fiber or vessel to collapse is controlled by its lumen to fiber diameter ratio. Wood density affects this ratio. Vessel picking problems are influenced by vessel width, length and numbers per unit weight.



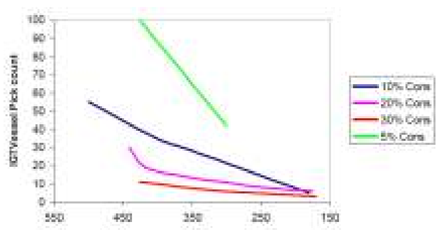
Picture courtesy PPRIC

Microphotographs 5 (A) Tropical hardwood vessel (B &C) Tropical hardwood vessels and fibers (D) SEM of eucalyptus paper surface showing vessels



Source: Heintze & Shallhorn, P&P Canada 96:11

Figure 2: Picking propensity of some hardwoo species



Source: Heintze & Shallhorn, P&P Canada 96:11

Figure 3: Effect of refining and consistency on vessels picking

Fine, well bonded reinforcing fibers give Z direction strength, and helps in holding the vessels in place. Better bonding reduces vessel picking. Good refining is essential, probably in the range of 100kwhr/t. This means that hardwoods should ideally be refined separately from the softwood. Refining lowers the freeness, so try to avoid other factors that may affect drainage, i.e. keep broke out of the hardwood refining line. At least one N. American coated paper producer thickens their hardwood and then puts it through a high consistency refiner. This applies lots of specific energy without lowering the freeness much. The vessels picking of some of the hardwoods is given in Figures 2 and 3.

Literature reports that hydrocyclone cleaning can remove tropical hardwoods vessels. They can be refined separately and returned to the main stream. This does not work with hardwoods. Vessels picking decreases as wet pressing increased. Surface sizing is extremely important for coated and uncoated papers. High filler contents are positively correlated with vessels picking and they interfere with bonding. Z-direction of distribution of fillers also affects vessel picking. Vessels on the surface of the base sheet prevent coating penetration into the base sheet. If the vessel is not well bonded to the base sheet, then a pickout can occur during offset printing (Microphotographs 6). The base of the pit left in the paper will be free of coating. Coating can pick during offset printing for the reasons other than the presence of vessels. In these cases the pit left on the coated surface will have traces of coating there. Microscopic examination can resolve the differences between the two types of defect (Microphotographs 7). Base paper surface strength was found to be the chief papermaking factor influencing both types of coating defects.

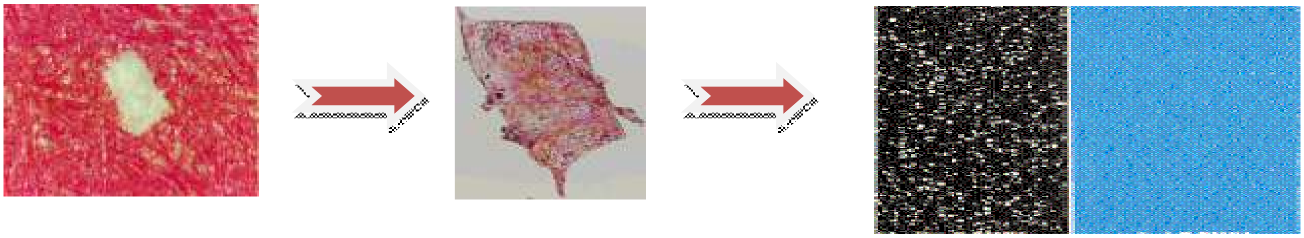
Vessels on the surface of the base sheet prevent coating penetration into the base sheet. If the vessel is not well bonded to the base sheet, then a pickout can occur during offset printing .

BIOTECHNOLOGICAL APPROACH FOR PRESS PICKING

Cellulose treatment is also found effective to mitigate vessel picking. The enzyme treatment reduces vessel picking by 85% when 5% slurry of bleached kraft hardwood pulp was treated with 0.5% (w/w) of cellulase at 50°C, pH 5 for 4 h and then the slurry was diluted to consistency level of 3% and beaten to a CSF level of 450. At the same time, smoothness increases from 50 to 129 s, and tensile strength increases from 4.45 to 5.50. Drainage time increases slightly with enzyme treatment, but the difference was negligible[25].

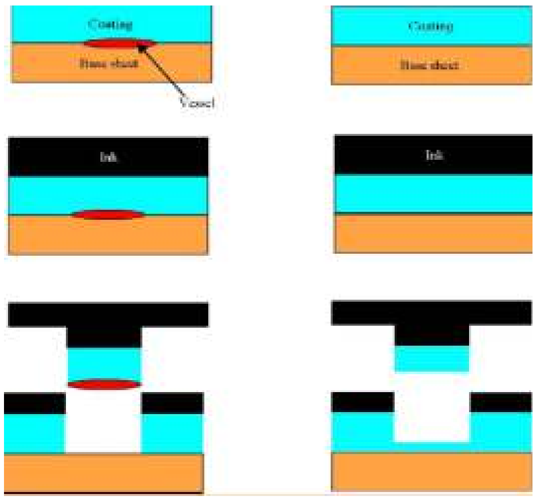
CHEMICAL TREATMENT

Use of wet strength resin mitigates linting problem by developing cross linking. A study carried out in BILT, Yamuna Nagar shows that addition of 1.5 kg/t of cationic fatty acid at wet end and 3 kg/t of poly hydroxylated resin at size press reduced the fluff content of paper by 59.7 % and 58.5 % on top and wire side of the paper respectively when tested with L&W GFL type fluff tester. The fluff contents in paper were reduced by 35.04 % when tested with



Picture courtesy PPRIC and Dutt et al., Bioenergy 2007, 3rd International Bioenergy Conference and Exhibition, Jyvaskyla (Finland), pp 667-672

Microphotographs 6: Removal of vessels during printing



Microphotographs 7: Two mechanisms for vessels and coating picking[24]

Para type fluff tester. The fluff content in paper was reduced by 47.05 % when tested with IGT printability tester. On the other hand, the surface strength of paper was improved from 13A to 14A and Scott bond from 270 to 285 J/m2. At printers end, printing impression was improved from 7500 to 12000 impressions per hour. The wastage in printing machine blanket due to cleaning reduced to 50 %. Cleaning of the blanket was reduced from two times to one time for one paper reel of 400 kg. Overall, it can be concluded that the use of cationic fatty acid and poly hydroxylated resin shows an improvement in runnability of paper machine with improved quality of paper[26]. Cationic amino resin (Nova Royal) is found successful to reduce fluff content to 22-24 mgm/km length of paper against 28-50 mgm/km length of paper with wheat straw soda pulp furnish.

OTHER CAUSES AND REMEDIES

- Increase refining
- Stock preparation additives should be added according to increased surface area Optimization of wet end bonding additives
- Use of PCC in place of GCC at the same dosing of size chemical results loss of sizing. However, the refractive index of GCC and PCC is same.
- Check white water pH to be sure that it is within range
- Check all presses. Paper carrier rolls and fly rolls to be sure that they are clean
- Check the freeness of the stock. Excessively free or excessively slow stock will contribute to pick outs
- High moisture content in the wet web entering a press will

Table 3: Fluff content tested in writing and printing paper of 70 g/m² (A) L&W GFL type fluff tester (B) Para type fluff tester (C) IGT printability tester

A

Sample No	Fluff content in 70 g/m² writing and printing paper			
	Control		Plant trial	
	Top side mg/m²	Wire side mg/m²	Top side mg/m²	Wire side mg/m²
S1	0.890	0.655	0.390	0.255
S2	0.780	0.560	0.280	0.260
S3	1.010	0.760	0.420	0.360
S4	0.685	0.560	0.355	0.260
S5	0.855	0.780	0.255	0.240
Average	0.844	0.663	0.340	0.275

B

Sample No	Fluff content in 70 g/m² writing and printing paper			
	Control		Plant trial	
	Fluff range (nos./in²/5 sheets)	Weight average (nos./in²/5 sheets)	Fluff range (nos./in²/5 sheets)	Weight average (nos./in²/5 sheets)
S1	200-240	210	180-200	190
S2	180-220	205	150-180	160
S3	220-260	235	100-150	120
S4	200-280	255	100-160	140
S5	220-300	265	120-180	150
Average	180-300	234	100-200	152

C

Sample No	Fluff content in 70 g/m² writing and printing paper	
	Control (Scale 1–6)	Plant trial (Scale 1–6)
S1	3	2
S2	4	2
S3	3	2
S4	4	1
S5	3	2
Average	3.4	1.8

contribute to pick outs

Check presses and felts for pitch build-up

Check the internal sizing of the sheet and dope the system with size and alum if necessary

Check the temperature of lead-in dryers to be sure the temperature are properly graduated

A cold or water logged dryer will contribute to pick outs. Check the dryer temperature

Check for worn or damaged dryer felt

Lead temperature in dryer section is too high: Reduce the temperature of lead dryer and check the temperature graduation with a hand pyrometer

Reduce refining or make a possible furnish change

High water pH:

Adjust the sheet moisture and or size temperature to increase the size press pick up

Increase the tub size starch concentration

Poor surface sizing: Increase the wet end pressing

Reduce the water in the sheet if possible

Reduce the refining and or refining to free up the stock if possible

Sheet moisture too high entering the presses or dryers: slow down the machine

High ash content in the sheet:

Check the ash content and reduce if other tests will permit. A high ash content will contribute to fuzz

Increase FPR

Adjust wet end bonding additives

Dirty felts, dryers and rolls

CONCLUSION

The tyloses when present on paper surface lead to fluff generation in dryer section of paper machine or printing blankets. This problem may be eradicated by treating the wood chips with hot black liquor and balloon like structure burst which facilitates faster penetration of cooking liquor. Presteaming of wood chips also causes shrinkages of balloon like structure. The parenchymatous cells so called pith cells present in agro-based raw materials also leads to the generation of fluff. Immature trees have weaker cells due to incomplete cellulose formation. When such type of fibers are subjected to mechanical attrition, instead of removal of primary wall and fibrillation, more fiber cuttings takes place. The primary wall is permeable to water but does not participate in bond formation. These non-fibrous elements have larger surface area than fibers and their presence affect fiber bonding adversely. The loosely bonded fibers from the paper sheet adhere on press rolls or dryers during sheet making and contribute to fluff problem. The hardwood vessels also contribute towards press picking and hydrocyclone cleaning can remove tropical hardwoods vessels. They can be refined separately and returned to the main stream. This does not work with hardwoods. Vessels picking decreases as wet pressing increased. The enzyme treatment mitigates vessel picking by 85%. Use of wet end bonding additives like cationic fatty acid, poly hydroxylated resin and cationic amino resin decreases the fluff problem. The other process parameters like refining, use of fillers of larger surface are and addition of insufficient wet end bonding additives, sheet moisture, poor fine retention, white water pH also causes fluff generation.

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