Contaminants in Recycled Paper and Their Removal

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ABSTRACT

The presence of contaminants in waste paper remains a formidable barrier for increased use of recycled fibre for all paper grades. In Indian context, very little information is available about the nature of contaminants due to which mills using waste papers continue to face problems during processing. In the present paper, the various types of contaminants present in the waste paper and their removal strategies for effective utilisation of recycled fibre in various grades of paper have been discussed. The various strategies for removal of stickies, wax, wet strength resins, ink particles and fillers have been highlighted.

INTRODUCTION

The use of recycled fibre within the paper industry has increased significantly over the past few years, driven by various factors including environmental concerns, economic considerations, legislation and the market demand for paper containing recycled fiber. The current trend is recycling of more secondary fibre into all grades of papers and this has forced papermakers to process lower-quality waste papers containing much higher level of contaminants than the preferred higher-quality grades.

The Indian paper Industry is using waste paper as a fibrous material since 1970s as an alternate to woody raw materials in addition to non-wood fibre resources to meet the shortfall in total paper & board demand. With the present recovery rate of 18.7%, the industry is using a wide variety of indigenous and imported waste papers. It is estimated that due to restricted availability of raw materials, the shortage in paper is likely to be of the order of around 3.64 million tons by 2010, which would require import of paper as well as waste paper and pulp for domestic conversion in to paper.

The presence of contaminants is waste paper remains a formidable barrier for increased due of recycled fibre for all paper grade. In the United States alone, the estimated cost of stickie contaminants - in terms of lost production item, lost raw material, downgraded product quality, and landfill costs - could be as high as US$ 700 million annually.

Currently, Indian pulp & paper industry is gearing up for the gradation of waste papers, however, very little information is available about the nature of contaminants and due to which mills using waste papers continue to face problems during processing. In order to best understand how to deal with these contaminants in a recycling mill, an

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understanding of fundamental properties is necessary. In the last two years CPPRI has conducted an exhaustive study on contaminant removal strategies broadly covering the stickies and non-stickies type of contaminants. The present paper discusses the various types of contaminants present in the waste paper and their removal strategies for effective utilisation of recycled fibre in various grades of paper.

DISCUSSION

CONTAMINANTS IN RECOVERED PAPERS

The wastepaper use introduces many contaminants to the papermaking system as recycled fiber often contains a wide variety of contaminants such as pressure-sensitive adhesives, hot melts, waxes, inks, seam bindings, latexes, wet-strength resins etc. These contaminants can be classified as external or internal, as shown in Table-I.

External contaminants are not physically or chemically attached to paper or board but are included in recovered paper bales and can be removed by pre-inspection of bales and subsequently in the pulping stage via trash removal devices. Internal contaminants, on the other hand, are physically or chemically attached or are imbedded in the paper or board. Internal contaminants can be further divided into two groups.

(i) **Soluble Contaminants** Like starch, alum and some glues which flow with water and can be

Table-I

CONTAMINANTS IN RECOVERED PAPERS

External	Internal		
	Soluble	Insoluble	
		Nonstickies	Stickies
Sand	Starch	Plastic	Hot melts
Glass	Alum	Fillers	Wax
Wires	Soluble glue	Wet strength	PSA
	Sizing agent	Ink	Latex
Golf balls	Notes:		
Sneakers	1. PSA = Pressure - sensitive adhesives		
Wooden boards	2. Wax may or may not be sticky, depending on temperature.		
Watches	3. Certain components of inks may be water soluble components may be sticky or nonstickies.		
Engine blocks			
Kitchen sinks			
Styrofoam			
Cans			

Table-II

TACKINESS OF STICKIES AND HOT MELT

	Tackiness		
Contaminant	25°C	50°C	65°C
Stickies	Yes	Yes	Yes
Hot melt	No	No	Slightly

handled with proper water clarification for mill reuse and discharge.

(II) Insoluble Contaminants can be divided into

Non stickies - Fillers wet strength plastic, styrofoam and inks

Stickies - hot melts, pressure sensitive adhesives, latex and wax

These compounds are composed of several ingredients, some of which may be soluble in aqueous medium. The insoluble components may or may not be sticky. The water insoluble type contaminants are generally considered more troublesome to papermaking operation and, therefore, need closer monitoring.

THE PROBLEM OF 'STICKIES'

Stickies is a term that refers to hydrophobic components used in the manufacture of a paper product where these components are used as contact adhesives or hot melts. The most common components used as contact adhesives are styrene butadiene rubber (SBR), vinyl acrylates, polyisoprene, and polybutadiene. Hot melts are always mixtures of various components (e.g. wax and tackifying resins). It is the property of contact adhesion at wet and dryer temperatures that causes stickies to affect machine runnability, regardless of their chemical composition.

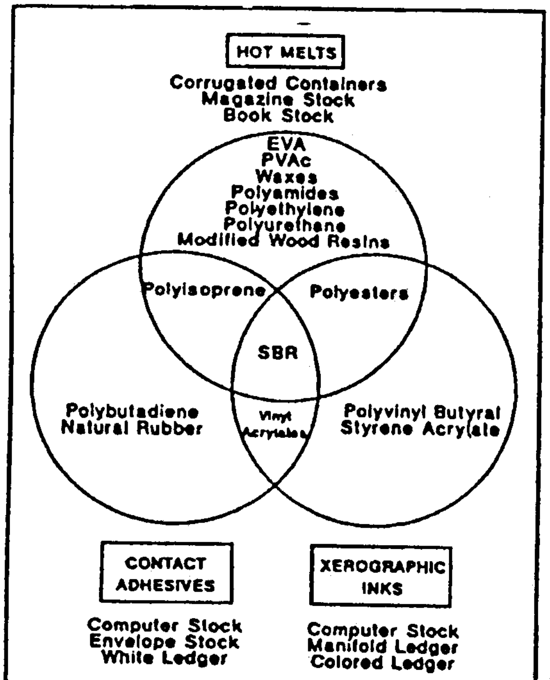

FIG. 1. SOURCE AND COMPONENTS OF STICKIES.

Figure 1 illustrates the source and components of various stickies.

Stickies are gelatinous tacky contaminants which originate from the pressure sensitive adhesives, while hot melts are broken fragments of the bindings in the magazines. Under normal deinking and paper machine operating conditions, hot melts are not tacky and do not stick as illustrated in Table-II. Conversely, stickies remain tacky under these conditions.

The characteristics of stickies include hydrophobicity, low surface energy, tackiness, and deformability due to which they frequently agglomerate and deposit on wire, felts, or other parts of paper machines or show on the sheet as spots. DSC analysis revealed that melt transitions for these organic materials occur with in three temperature ranges: 50-60°C 92-105°C and 115-123°C, emphasizing the need to operate at the lowest temperature possible. The most common problems caused by stickies are

- Increased machine downtime caused by breaks and required cleanups
- Reduced product quality caused by picking, pinholes and poor appearance
- Increased replacement costs for wires and felts
- Reduced efficiency of converting and/or printing operations
- Limited levels of fibre substitution

STICKIES CLASSIFICATION

Stickies can be classified into two groups based on their size

Macro stickies- materials that are large enough to be retained on a 0.15 mm or 0.10

Table-III

STICKIES CLASSIFICATION ON THE BASIS OF SIZE

Type	Screen scale	Average diameter
Large	Retained on 35 mesh screen	> 0.42 mm
Medium	Retained on 200 mesh screen	0.074- 0.42 mm
Small	Pass through 200 mesh screen	< 0.074 mm

mm laboratory flat screen plate (non-pressurized).

Micro stickies- which pass through such flat screen plate with the filtrate.

The size of stickies may vary as they move through the system due to their breakup and re-agglomeration. According to the criteria developed by M. Doshi, stickies can be classified on the basis of size, as given in Table-III.

Medium size stickies cause most of the problems becuase they are not easily removed mechanically and are most prone to deposition.

Table-IV

ANALYTICAL METHODS FOR QUANTIFYING MICROSTICKIES LOAD IN WATER CIRCUITS

Test method	Stickies quantification	Stickies selectivity
Extraction	+	-
IR sepctroscopy	-	+
Chemical oxygen demand	+	-
Cationic demand	+	-
Conductivity	+	-

Table-V

NONCOLLOIDAL PARTICLE SIZE FROM VARIOUS LOCATIONS ON PAPER MACHINE[a]

	Particle size, μm[b]
Reverse-cleaner rejects	32 - 40
Forward-cleaner rejects	20 - 30
Forward-cleaner accepts	40
Decker rejects	21
Decker accepts	16
Low density to paper machine	40 - 50

[a]Longview FIbre Co., Longview, WA

[b]Measured with Coulter Counter, which can not detect particles in the colloidal or near- colloidal range

QUANTIFICATION OF STICKIES

To control stickies related problems, a method for measuring the active stickies content must first be developed. Till date there is no standard method available to quantify stickies in a pulp sample. Most recycling plants, vendor companies and research organisations have developed their own test methods for stickies but all these methods have a variation to suit the testing location.

The most accepted method so far is the use of a slotted screen to concentrate contaminants in screen rejects. Somerville with a 0.006 inch slotted screen is widely used, however it is dependent on small sized contaminants that pass through screen.

The water soluble dye method involves the use of Parker water-soluble black ink to colour fibres and not stickies. Some mills simply count the number of contaminants while others also measure the area of contaminants under microscope by the TAPPI dirt count method or by image analysis.

Table-IV lists the current chemical analytical methods that are used to measure microstickies. As observed, non of the methods meets the dual requirements of stickies selectivity and quantification.

Table V shows a break down of particle sizes and locations on the paper machine for non colloidal stickies.

STRATEGIES FOR CONTAMINANT REMOVAL

1. Removal of Stickies

There are five approaches used to combat stickies which include both chemical and mechanical approaches

- Furnish selection i.e. removing all sticky material before processing
- Improved pulping and deflaking operation
- Screening and cleaning
- Dispersion
- Use of additives to prevent re-agglomeration

(i) Furnish selection

To prevent the entry of stickies, it is very important that criteria be established for acceptable and unacceptable waste paper. Depending upon the nature of the furnish, final product and specific problem or customer needs, it is desirable to measure the concentration of stickies, plastics, clay, brightness, freeness, ground wood content or fibre length distribution.

(ii) Improved Pulping & Deflaking

It includes use of modern pulpers equipped with auxillary equipment like ragger, junker and a secondary pulper. The use of drum pulper also facilitates to keep the contaminant size bigger so as to be rejected by associated rotary screens.

(iii) Screening and Cleaning

Recommended screening schemes utilise forward feed of accepts during secondary as well as primary stage, using the same screen design and size in both stages. The forward feed approach eliminates cycle-up between 1^{0} and 2^{0} stages. Slotted fine screens (0.15-0.25 mm) are more efficient for recycle-related contaminants than traditional hole screens. This allows standard equipment to handle more capacity. Mechanical dispersion equipment is now used to disperse stickies after screening is complete to further reduce stickies particle size.

In an another study, it is reported that by increasing the reject rate from 1500 L/min to 3000 L/min in fine screens (0.008 inch slots) the stickies separation efficiency has increased from 34% to 49%.

Cleaners are used to remove contaminants based on their density difference. As the hydrocyclones dia decreases its efficiency in removing small size contaminant increases. Reverse hydrocyclones or through flow cleaners are used to remove low-density contaminants. Compared to reverse hydrocyclones, through flow cleaners are an edge over as the reject stream is only 10% by volume compared to 55% in case of hydrocyclones which require secondary and tertiary stages to recover usable fibre. However the contaminant removal efficiency is higher than throughflow cleaners. In one of the studies it was shown that increasing reject rate from 85 L/min to 186 L/min in Gyroclean, the stickies removal efficiency increased from 79% to 87%.

(iv) Dispersion

The basis of dispersion technology is chemical enhancement of the thermal and mechanical characteristics of the wastepaper repulping process. These repulping characteristics work together to break down large stickies to small, discrete particles. Dispersion chemistry also acts to stabilise small stickies to prevent reagglomeration. Dry end stickies deposition and converting bottlenecks such as pickouts and breaks are related to large size stickies. Reducing individual stickies surface area via dispersion technology also reduces the stickies/dryer fabric bond strength.

An application of dispersion is breaking up waxes or hot melts in OCC stock and in the deinking area. However, when ink particles are broken up into smaller sized particles and dispersed, brightness will decrease. In this instance, dispersion should be followed by an ink removal step to improve brightness.

(V) Additives

A final strategy to combat stickies involves use of chemical additives. These include addition of talc, solvents and dispersants, cationic polymers, sythetic fibres, zirconium compounds and alum sequestering agents.

(a) Talc One of the important characteristics of talc its hydrophobic surface, which has an affinity for stickies, and hydrophillic edge, which allows easy dispersion of talc in water. It should be added to a deink stock storage chest to allow time for the talc to contact and detackify the stickies. Talc is not effective on stickies, which are not tacky at the head box temperature but become tacky at the dryer temperature.

(b) Solvents and dispersants Anionic dispersants keep small stickies suspended in a slurry by inducing a negative charge on them which repels other negatively charged stickies, while non-ionic dispersants with one hydrophobic and one hydrophillic end, attach its hydrophobic end to stickies leaving hydrophillic end exposed to water with no affinity for stickies, thus preventing agglomeration.

(c) Cationic polymer Stock addition of low molecular weight, high charge density cationic polymers is widely used for charge neutralisation/stickies control. The phenomena is 'fixing' of anionic stickies to anionic fibre with low molecular weight high cationic charged polymer. These polymers can be added at the thick stock chest, fan pump or at the head box or it can be sprayed on machine wires to minimise deposition of stickies.

(d) Synthetic fibres Synthetic fibres, such as polypropylene fibres have an affinity for ink and organic contaminants and can be used to scavenge them from a system. These are useful only at temperatures and pH where stickies tackiness is high and are not very effective for stickies which are not tacky at head box temperature but become tacky at dryer temperature. Since they do not bond well with cellulose fibres, they may cause problems during paper machine operation, hence their use has been limited.

(e) Zirconium compounds Zirconium compounds are used as stickies control agents by detackifying stickies from hot melts and pressure sensitive adhesives with most of them ending up in the final product. These compounds are available in liquid form and any excess can accumulate in the white water, when they prevent the build up of stickies due to water closure.

(f) Alum sequestering agents An excess alum can lead to coagulation of stickies in the secondary fibre stock. Sequestering agent can be used to scavenge excess alum aluminium ions, which could later be available, if alum concentration decreased.

2. REMOVAL OF WAX

The waxes used in packaging are primarily petroleum waxes. Some synthetic waxes such as polyethylene andFischer Tropsh waxes are also used, particularly in hot melt adhesives.

Petroleum wax and wax based hot-melt coatings and adhesives are hydrophobic. Wax behaviour in a mill is largely a function of its softening and melting points and its viscosity when it melts. When wax impregnated paper is repulped at moderate temperatures (60°C), the wax melts and with relatively low viscosity, readily disperses throughout the pulp. however if the wax is initially melted and the temperature falls below the melt point of the wax during screening and cleaning, wax may deposit on paper fibres, hindering separation of wax and fibre.

Several lab methods have been tried which included

(i) Feeding of shredded wax coated paper to refiners with water at 88°C followed by washing on a side hill screen resulting in reduction of wax content to 1%.

(ii) Pulping with sodium silicate and aluminium stearate under alkaline conditions (high pH) or an alkyl or aryl sulfonate under acidic conditions (low pH) followed by flotation.

(iii) Use of nonionic surfactants at high temperature (82°C) to aid dispersal and subsequent removal by washings.

(iv) Use of kraft black liquor as pulping medium where lignin sulfonate salts act as dispersants.

(v) Hot solvent extraction of waxed paper.

3. REMOVAL OF WET STRENGTH RESINS

Wet strength imparted to papers using wet strength additives, makes the paper contaminated,

Table-VI

BENEFITS OF CHEMI-MECHANICAL PROCESS FOR REMOVAL OF WET STRENGT RESINS

Basis- 50 tpd (at Machine chest)

Particulars	Mechanical process	Chemi-mechanical process
Chemical Requirement. kg/t	Not required	Required
Electrical energy requirement	High	Low
Steam to raise process temp.	Required (40-50°C)	Required (70-80°C)
Raw material requirement t/t	2.2	1.2
Process yield. % (avg.)	45	85
Pulping time	2 - 4 hrs	40 - 60 min.
Number of Batches/day	6 minimum 12 maximum	24 minimun 40 maximum
Fiber loss %	45 + (10% ash)	+ (10% ash)
Productivity	Base	3-4 times of base
Rejects going to land fill t/d	60.5	9.0

Source - CPPRI Data

causing problems during repulping with end results of high energy consumption, low yields, and high reject rates. Based on extensive R &D work CPPRI has established a processing technology for removal of wet strength resins from paper stock. The process is a combination of chemical and mechanical treatment. The studies have revealed that it is important to identify the resin type in the paper before it is subjected to repulping since different resins would require different chemical treatment based on the chemistry. Table VI summarises the benefits of the chemimechanical process.

Typical process conditions required to repulp the wet strength papers will include:

- Chemical treatment - Selection of appropriate chemical
- System pH - High consistency desirable
- Temperature - High temperature desirable
- Shear rate - High shearing is desirable
- Process equipment - Appropriate selection of equipment would increase the efficiency

Acid curing resin would require acidic pH for repulping while neutral/alkaline curing resin would require neutral to alkaline pH for repulping depending upon the amount of resin of the paper. A higher temperature more than 60°C is required for repulping of wet strength paper as the high temperature facilitates the penetration of chemical into the paper. A minimum retention time of 30 minutes is essential for reaction to take place between resin and chemical aids. The chemicals include alum, sulphuric acid, NaOH and oxidising agents H_2O_2, $Ca(OCI)_2$ and potassium monopersulphate.

4. REMOVAL OF INK PARTICLES

The presence of specks in the finished paper is due to presence of ink particles, which have not been efficiently removed. Ink can be removed either by washing or flotation technology or a combination of both. Flotation removes paticles that are too small to be removed by screens and cleaners and yet are too big to be removed by washing. Washing is most effecient at removing the smallest particles of ink. The washing and flotation operations require chemicals to help them perform efficiently.

WASH DEINKING

In wash deinking, the ink is detached from the waste papers by using deinking chemicals, i.e.wetting agent and surfactant. The detached ink particles are generally less than 10 µm and well dispersed in the pulp slurry. These dispersed inks are removed from the pulp through repeated dilution and thickening actions. This washing technique is suitable for handling waste papers with never dried inks, i.e. ONP or old waste newspapers, which do not form visible specks in the pulping step.

FLOTATION DEINKING

The flotation deinking process is based on ink aglomerations chemistry. After the ink is detached from waste paper in the pulping step, the ink particles are agglomerated by using a suitable collector, e.g. fatty acid soap. These agglomerates generally range from 30 to 100 µm in size and are hydrophilic or water loving nature. They would remain a stable suspension in the pulp slurry before

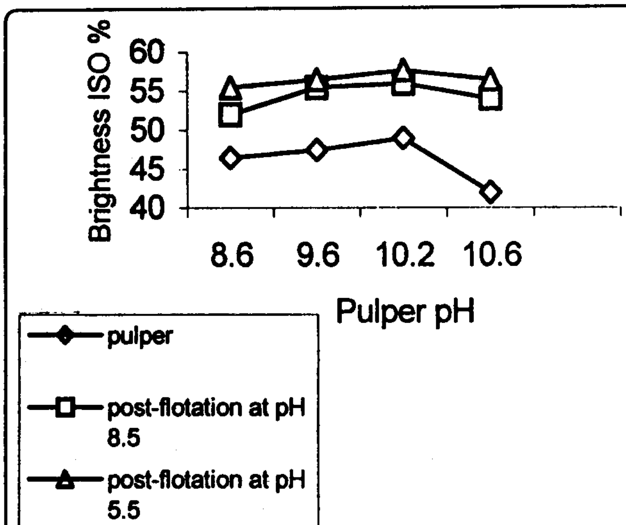

FIG. 2: EFFECT OF ALKALINITY ON THE BRIGHTNESS

the flotation cell operation. However, upon entering the flotation cell, the agglomerates are modified to become hydrophobic or water repellant with the addition of lime. In the flotation cells, these hydrophobic ink agglomerates readily attach to the

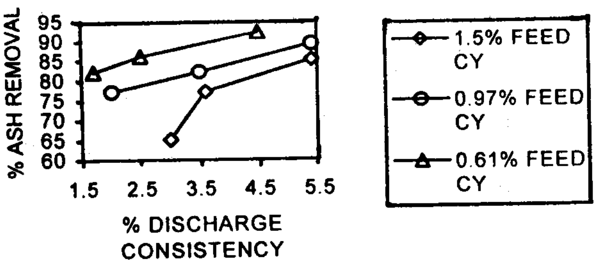

FIG. 3 : INFLUENCE OF FEED AND DISCHARGE CONSISTENCY ON WASHER PERFORMANCE

air bubbles and are discharged as foam sludge. The flotation deinking technique can handle both ONP and coated waste papers, i.e. magazines, which form bigger ink particles in the pulping step. This type of waste paper cannot be handled by the washing deinking technique that requires the formation of micro sized ink particles.

The efficiency of any of these systems depends on

- type of ink in the paper
- slection of appropriate deinking formulation
- selection of appropriate system configurations.

Though a wide variety of printed waste paper are being used for the production of DIP for the manufacture of newsprint and writing/printing grades of paper, however, the common varieties are ONP/OMG and MOW/SOP which are extensively used. Process chemistry plays a vital role in a deinking system and can impact operating cost, yield, brightness, strength and environmental characteristics of effluent and solid waste streams.

Fig. 2 shows the effect of alkalinity on the brightness after pulping and flotation deinking. Above pH 10.2 the brightness decreases. At post flotation the acid shock given to simulate the machine conditions have showed improved brightness.

5. REMOVAL OF FILLERS

The washing process can be applied very effectievly to separate filler and other fine contaminants. Ash levels can be reduced to 1% in the final pulp by high-efficiency washers. The ash removal efficiency of washer increases as the discharged consistency is increased at a given inlet consistency as shown in Figure 3. Low feed consistencies give better hydraulic split in a washer, which in turn improves ash removal efficiencies.

Conventional washers and also flotation to a certain extent will also reduce the ash content of the pulp. One of the main considerations in reducing the ash content of the MOW furnish is the effect on yield, becuase washing will also remove a proportion of the fines in the pulp. This raises freeness and strength, but lowers the yield and produces more sludge, which is a concern.

STATUS IN INDIAN MILLS

By and large the system components and unit operations incorporated in the majority of recycled fibre based mills are inadequate to attain acceptable cleanliness level in the resulting pulp. In most of the cases the system configuration in the mills is inappropriate for efficient contaminant removal. The waste paper process need initial size separation for bigger contaminates/plastics trash followed by a combination of coarse density separation and size separation before the smaller contaminants like ink and coating can be treated. The energy requirement for such sophisticated cleaning system is the major consideration for smaller units to adopt the right process. The lack of support from the indigenous equipment manufactures to develop energy efficient design of cleaning equipment to cater to the small and medium sector is also a reason for Indian units to limit their process to most primitive and inefficient systems which results in low product yields, high rejects leading to excessive fibre loss and poor quality of the end product.

Waste paper shushing and pulp cleaning systems are available, however systems for removing inks or dispersing it to invisible entity are not well developed and practiced in India.

CONCLUSION

Although there are no easy answers to waste paper related problems, an organised approach to identify and solve the problems will be rewarded. Adoption of the appropriate technology or combination of technologies (chemical & mechanical treatments) must be co-ordinated into a comprehensive stickies control treatment program specifically designed to solve each individual mill's wastepaper stickies problems. An understanding of mechanical influences and limitations and the optimisation of the process and wet-end chemistry will maximise the effectiveness of the treatment programme. Good problem investigation techniques to identify the causes of a problem will enable the correct technology to be chosen to provide the most cost effective treatment. Contaminant control is the key to making wastepaper payoff.

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