New trends in deinking technology

Removing difficult inks from wastepaper

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Future deinking facilities must be able to cope with a variety of paper stocks, including those containing difficult-to-disperse inks.

The amount of wastepaper containing difficult-to-disperse inks is rapidly growing. Xerography and associated laser printing techniques are an important and growing source of contamination in computer printout papers, office copy paper, and ledger paper in general (*1*).

Conventional deinking processes of washing and flotation are not very effective at reclaiming speck-free fiber (*2, 3*). As a result, paper stocks containing such contaminants have been downgraded in their final product applications far below the quality of the fiber these papers contain.

Annual laser printer shipments in the United States were expected to increase from less than 10,000 in 1983 to over 400,000 in 1989 (*4*).

A review of the compositions of laser and other electrostatic toners has been written by Seldin (*5*). The result shows that copies emanating from a laser printer are identical in properties to ordinary xerographic copying machines. Therefore, problems in recycling copies from laser printers are identical to those of office copiers.

This discussion will focus on the characteristics of the contaminant, approaches to removal, and systems commercially applied. Further, a basic design approach will be suggested, along with trends in new system design.

Characteristics of the contaminant

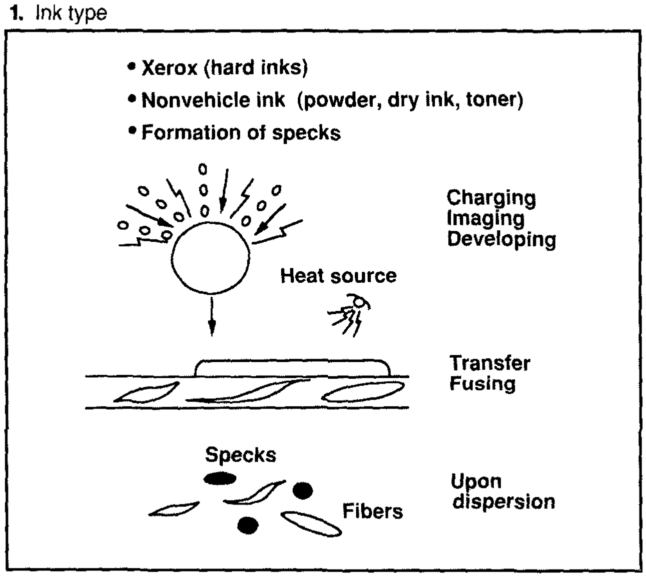
Inks have traditionally consisted of colored pigments that provide contrast and a vehicle for printing fluidity during application and subsequent pigment binding. Some modern inks, such as those associated with xerography and laser printing, consist of fine pellets fixed by fusion.

These inks are found in photocopies, government publications, computer printouts, and general office waste. This ink cannot be broken into individual pigment particles because of the fusion process of printing.

Caustic swells the fiber and in conjunction with the high-shear hydraulic action, such as in pulpers and mechanical dispersion units, the inks held within the binders (toners) are broken off the fiber in the form of various-size particles (*6*).

A typical example of the process is found in **Fig. 1**. In the xerographic process, imaging is on an electrostatically-charged metal drum. Light exposure discharges the drum. Ink powder (toner and carrier) is cascaded over the image surface, adhering to the unexposed (dark) areas. The ink releases to a static-charged paper. The paper is then conveyed to a heated zone where the toner is thermally fused. Xerography inks are thermal plastics mixed with carbon black.

1. Ink type



With laser imaging, the principle is somewhat the same but with two major differences.

First, imaging is done with a computer-directed laser which "prints" on a plastic film. Second, ink is fixed much more rapidly, using a combination of heat and pressure.

The major problem of these printing techniques in terms of recycling is the toners (binders).

An investigation was made of six different photocopying processes (*3*). The systems involved are listed in **Table I**, which shows the significant differences in the toner composition in the fusing systems used.

Three systems used styrene/acrylic based toner, one is polyester based, one is a pure acrylic, and one is based on liquid solvent.

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I. Deinking performance of various office copier wastes: machine descriptions

Machine	*Fusing systems*	*Toner*	*Roll lubrication*
1	Hot roll	Styrene/Acrylic	Teflon/Silicone
2	Radiant	Polyester	None
3	Heat/Pressure	Styrene/Acrylic	Silicone
4	Radiant	Acrylic	None
5	Evaporative	Liquid solvent	N/A
6	Heat/Pressure	Styrene/Acrylic	Silicone

II. Deinking performance of various office copier wastes: flotation accept dirt counts

Machine	*Dirt count, specks/g*
1	179
2	990
3	21
4	17
5	44
6	10

III. Pulp quality levels

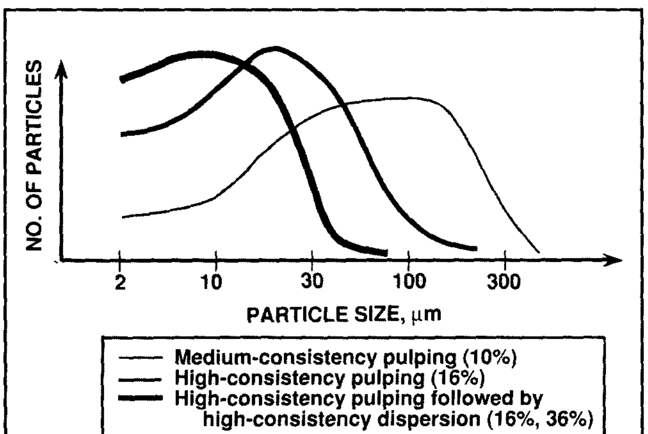
*Plant**	*Softwood fiber, %*	*Dirt speck, ppm*	*Brightness, GE*	*CSF*
1	28	500	79.8	480
2	50	350	82.0	520
3	24	125	83.1	580
4	30	76	80.7	490
5	48	12	85.5	430
6	48	6	78.4	420

Plants 1-3: Tissue and toweling.
Plants 4-6: Printing and writing
*All plants use up to 10% difficult-to-disperse inks paper stocks.

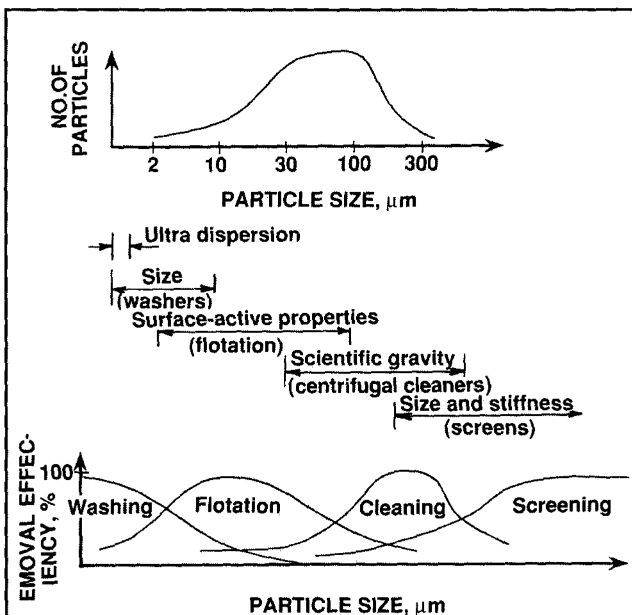
IV. Unit operations efficiencies

Operation	*Efficiency of dirt speck removal, %*
Screening (0.006-0.010-in. slots)	15
Cleaners (reverse flow)	20
Cleaners (forward)	75
Flotation cells	70
Washing	10

2. Particle size distribution



3. Particle size distribution in the pulper (top) and unit removal efficiency (bottom)



Speck size can be large, and typical dirt counts can approach 1000 specks/g with various copying techniques, as represented in **Table II**.

Similar binders also can be found in flexo printing for newspaper and other graphic papers. Ink compositions of acrylic and acrylic copolymer resins are a major component of such techniques (*7*).

To be successful, the fiber recovered from these processes must be of good enough quality to be used in the manufacture of tissue and toweling grades and, to a lesser extent, in high-grade printing and writing papers.

Historically, the removal of ink from the fiber would lead to a finely dispersed ink particle which could be easily removed by direct washing techniques.

However, today's binders, when removed from the fiber, result in relatively large (>20 μm) particles. These particles cannot be removed effectively by standard washing techniques or by combining washing and flotation techniques.

Pulp quality levels of representative deinking plants are shown in **Table III**. All of these plants have either washing or a combination of washing and flotation as unit operations. Plants 1–3 produce a pulp usable in tissue and toweling with TAPPI dirt count levels from 125 ppm to 550 ppm.

Plants 4–6 are producing a pulp grade suitable for printing and writing papers, with dirt count levels from approximately 6 ppm to 76 ppm. All of these plants cannot use difficult-to-disperse inks successfully but on occasion will have paper stocks composed of such inks.

In all cases when these paper stocks are present, the dirt speck levels increase to the point of unacceptability for their respective products.

Approaches to ink binder (toner) removal

The standard deinking techniques of chemical dispersion followed by mild mechanical dispersion and typical washing and flotation techniques have failed in meeting the challenge of these difficult-to-disperse ink binders.

Approaches undertaken during the past few years to overcome the processing difficulties can be grouped into two categories:

1. Ink-binder removal from fiber with the combination of mechanical dispersion and removal
2. Ink-binder removal from fiber with chemical agglomeration followed by removal.

Ink-binder removal from fiber: a combination of mechanical dispersion and removal

Having discussed the physical nature of the contaminant, what available means are worthwhile for consideration in a system for its removal?

First, screening separates by difference in size and stiffness. Centrifugal cleaning separates mainly by the difference in specific gravity, along with the particle shape affecting the drag forces. The two types of cleaners are: (a) forward cleaners for the removal of heavy particles, normally heavier than water, and (b) reverse-flow cleaners, which remove particles lighter than water.

Flotation separates by difference in wettability. Contaminants are rendered hydrophobic and, with the combination of air and various collectors, are removed from the fibers in the water phase.

Washing is basically a laundering technique whereby the particles are made significantly smaller and placed in a water affinity phase, removing the contaminants with the water through small openings (such as 100-mesh screen) and leaving the fibers.

Mechanical dispersion is where the particles are mechanically broken into smaller pieces. With mechanical dispersion, the particles are not removed from the fibers and require additional steps for their physical removal. These various unit operation steps and the efficiency of dirt removal are represented in **Table IV**.

The most disappointing unit operation is that of screening. Even with the fine slotted basket openings down to 0.006 in. (150 μm), the large particle is not effectively removed.

This low efficiency is explainable in the plate-like shape of the particles. Even though the diameter of the particles may be relatively large in comparison to the slot, the thickness is significantly less, which allows the contaminants to pass through the slot sideways.

Reverse-flow cleaners also are not very efficient. Even though some of the particles may have a lower density than water, the shape of the particles may deter their removal.

Forward cleaners, on the other hand, appear to have a very high removal efficiency. This high efficiency may also be attributed to the shape of the particles.

Flotation cells have also proven to be effective for removing these kinds of particles.

Washing, on the other hand, has proven to be ineffective for particle removal because of the size of the particles. The normal particle size range after medium-consistency pulping (10%) is 40 μm to 400 μm. Successful washing requires particles smaller than 25 μm.

Mechanical dispersion by itself will not remove the particles from the fiber–water solution. However, effective mechanical dispersion can break down 80% of the particles into sizes smaller than 40 μm, a size that can be removed by operational steps further down the line (**Fig. 2**) (*8*).

A typical medium-consistency pulping technique at approximately 10% will develop a distribution curve showing particle size ranging from 2 μm to more than 300 μm.

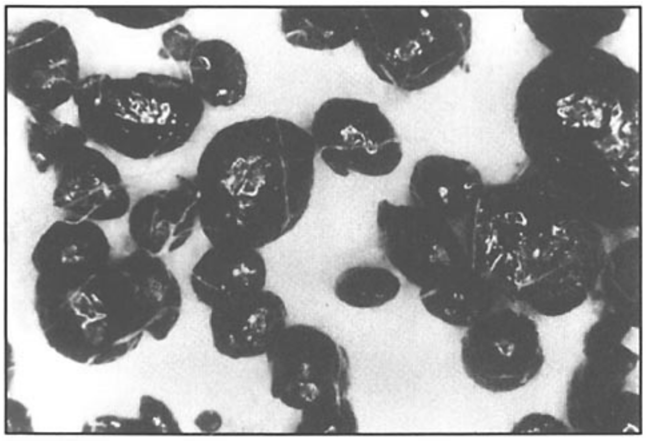
A redistribution will occur as a result of higher consistency pulping, such as at 16%.

Taking the high-consistency pulping further by applying high-consistency dispersion, such as 36%, again shifts the distribution curve drastically to the left, resulting in even fewer large particles in the pulp slurry.

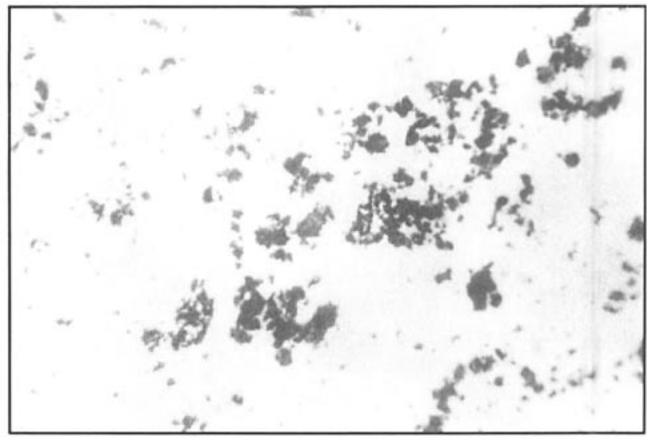
The combination of high-consistency pulping followed by high-consistency dispersion definitely decreases the visible ink particles. However, where high brightness is required, this combination, without including other treatment steps, will result in severe brightness losses (*9*).

This is the result of a combination of two forces. Decreasing the particle size increases the number of particles. In turn, the brightness as measured by reflectance will drop. Further, with mechanical dispersion some of the particles can be rendered small enough to be enjoined in the fiber matrix itself, which would not allow the particle to be removed.

The typical medium-consistency (10%) pulping technique develops a particle distribution as presented in **Fig.**



4. Fiber mix repulped with caustic alone



5. Fiber mix repulped with an agglomerating chemical formulation

3, with the appropriate removal efficiencies also shown for the unit operations discussed.

The exact shape of the distribution is very dependent upon the nature of the ink-binder and the pulping dispersion technique. This representation clearly shows that screening and washing, for particles having this type of distribution after the pulper, would be inadequate.

Even with the combination of standard flotation and forward cleaning, it appears that a sizable number of particles would remain in the final pulp product.

This representation indicates that extensive combinations of flotation and washing would be required if the particle distribution was not adjusted through pulper techniques and mechanical dispersion.

Ink-binder removal from fiber with chemical agglomeration followed by removal

An alternative to the extensive combination of mechanical dispersion and removal operations is the approach of agglomerating the particles for easy removal via screening and cleaning.

A process for removing electrostatic toners by absorbing them on polystyrene foam prills that were added to the pulper has been described (*2*). The approach proposed was developed for agglomeration of particles produced on laser printers and office copiers (*9*). This method is different from the washing and flotation methods currently used.

When a secondary fiber mix containing a high percentage of electrostatic toner is repulped with caustic alone, the toner particles remain as flat, angular flakes as shown in **Fig. 4**.

When the same furnish is repulped with an agglomerating chemical formulation, the toner agglomerates into rounded particles (**Fig. 5**).

The agglomerates are composed of toners and inks, as well as a substantial portion of filler and dirt. The shape of these rounded particles, which can be as large as 2-3 mm in diameter, allows removal by pressure screens, provided the slots are smaller than the particles.

Forward cleaners efficiently remove the smaller particles which pass through the screens. Because of their shape, the drag forces permit easy separation from the fiber.

This process would allow deinking plants which now have slotted screens and cleaners to successfully surmount the difficulties of laser printed inks.

There is a chemical cost which must be fully evaluated along with ensuring that pulper furnishes containing a high percentage of laser-printed papers can be provided. Low percentages of laser-printed papers in a furnish may not justify this approach.

V. Systems applied using various percentages of difficult-to-disperse inks

Mill					
1	Pulping 10%	Cleaning screening 3%	Forward cleaning 0.8%	Forward cleaning 0.8%	Washing 0.8%
2	Pulping 10%	Cleaning screening 3%	Dispersion 20%	Flotation 1%	Washing 1%
3	Pulping 10%	Dispersion 20%	Screening 1%	Flotation 1%	Washing 1%
4	Pulping 10%	Cleaning screening 3%	Dispersion 35%	Cleaning 0.8%	Washing 0.8%

Systems applied to deinking graphic papers (difficult-to-disperse inks)

A number of systems have been adapted in addressing the new types of ink binders, such as jet-print laser printing, Xerox copying printout, and ultraviolet inks. Examples of commercial installations utilizing various degrees of laser-printed inks are depicted in **Tables V and VI**.

Mills 1-5 are utilizing pulpers at approximately 10% consistency. These are older mills which have adapted within their operations in an attempt to use difficult-to-disperse ink papers. As a result, all of these mills are using existing pulpers. Each of these mills have used varying levels of difficult-to-disperse ink papers with a varying degree of success.

Both medium-consistency dispersion (20%) and high-consistency dispersion of approximately 35% are being used commercially. Mills 2, 3, 5, and 6 appear to consistently provide a quality level for low-grade tissue and toweling grades. All of these mills have, however,

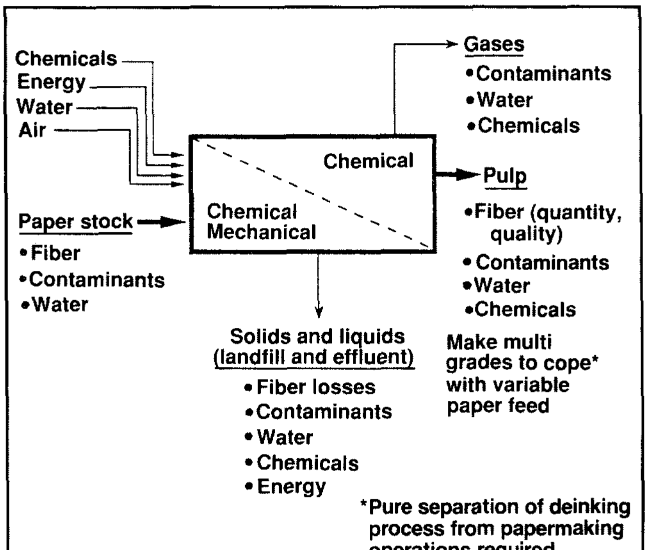
VI. Systems applied using various percentages of nondispersed inks

Mill								
5	Pulping 10%	Screening 3%	Washing 3%	Dispersion 20%	Flotation 1%	Two stages forward cleaning 0.8%	Two stages reverse cleaning 0.8%	Decker screening 2%
6	Pulping 16%	Cleaning screening 3%	Washing 3%	Dispersion 35%	Forward cleaning 1%	Reverse cleaning 1%	Washing 1%	
7	Pulping 16%	Dispersion 20%	Screening ...	Flotation 1%	Washing 1%	Screening ...		

VII. Trends in new system design

Options									
1	Agglomeration chemical pulping 10%	Cleaning screening 3%	Washing 3%	Two stage forward cleaners 0.8%	Reverse cleaning 0.8%	Washing 0.8%			
2	Pulping 16%	Cleaning screening 3%	Forward reverse cleaning 1%	Washing 1%	Dispersion 35%	Forward cleaning 0.8%	Washing 0.8%		
3	Pulping 16%	Cleaning screening 3%	Flotation 1%	Forward reverse cleaning 0.8%	Screening 0.8%	Washing 0.8%	Dispersion 35%	Forward cleaning 1%	Washing 1%

6. Total process overview of secondary fiber system



fallen short in providing a quality level for printing and writing papers.

In the mills depicted, dispersion is undertaken before fine forward cleaning or flotation.

Trends in new system design

With many of the present systems falling short in providing high-performance treatment of difficult-to-disperse inks, new systems and the adaptation of older systems to meet the challenge of these inks are proceeding into principally three areas.

These options are represented in **Table VII** and reflect the current thinking of many process engineering personnel in both Europe and North America.

Option 1 focuses on the chemical approach to agglomeration of the ink particles. This approach, if successful, logically will minimize the changes in existing deinking plants to meet the challenge of the contaminant. One of the difficulties in this approach is obtaining paper stocks on a sustained basis which have high percentages of laser-type inks. With the receiving of highly graded paper stocks or adjustments in the chemistry, this approach would lead to an effective solution of the problem.

Both Options 2 and 3 are a proposed advancement in the ink-binder removal from fibers with the combination of mechanical dispersion and removal. Both of these options attempt to alleviate the loss of pulp brightness due to the entrapment of small ink particles within the fiber. The approach of Option 2 involves dispersion in the pulper at the critical point above which minimum fine micron-size dirt particles are formed.

Following the pulper, both the combination of fine screening and forward and reverse cleaning are undertaken, along with washing. These steps are designed to remove as much of the ink particles as possible before major dispersion. Dispersion followed by a stage of forward cleaning along with an additional stage of washing are incorporated to remove the remaining ink particles.

Option 3 is similar to Option 2 except it places both flotation and one stage of washing before dispersion. Upon completion of dispersion, additional forward cleaning and washing is also proposed.

Each of these options have proven successful on a laboratory basis in producing a pulp suitable for printing and writing grade papers.

These approaches, however, have not been commercially installed and operated.

An additional trend in new system design is represented in **Fig. 6**.

It has become increasingly apparent that with these difficult-to-disperse inks maintaining a uniform quality on a sustained basis is not possible at the present time.

It is necessary to accept from a deinking system multiple grades to cope with the variable paper stock feeds.

This can mean up to three grade levels or more will be produced within the same system due to the variability of the paper stocks.

To accomplish this, it is necessary to separate the deinking process from the papermaking operations totally.

This process approach has enabled mills to utilize their deinking facilities at higher tonnage and quality levels than before the separation was undertaken. This process step is extremely critical to the future growth of deinking pulps and to the utilization of difficult-to-deink paper stock sources.

Conclusion

Wastepapers containing difficult-to-disperse inks are rapidly growing and are becoming more difficult to segregate in paper stocks provided to deinking facilities.

Conventional deinking processes of washing and flotation are not very effective for reclaiming speck-free fiber. All approaches commercially applied to date have not been successful in producing fiber qualities necessary for printing and writing grades. Commodity-grade tissue and toweling papers have successfully been produced with difficult-to-disperse inks utilizing mechanical dispersion at both 20% and 36% consistency ranges.

Mechanical dispersion without effective removal of the ink particles before high-consistency dispersion results in severe brightness loss.

Design trends for new systems are focusing on:

- Agglomerating of ink particles followed by screening and cleaning techniques
- High-consistency pulping followed by screening and cleaning, screening and flotation or washing followed by high-consistency dispersion, cleaning, and washing unit operations.

It is necessary to accept from a deinking system multiple grades of pulp to cope with the variable paper stock feeds. This process step is extremely critical to the future growth of deinking pulps and to the utilization of difficult-to-deink paper stock sources.□

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