FURTHER CONSIDERATIONS OF MAGNETIC DEINKING FOR WASTEPAPER RECYCLING MILLS

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ABSTRACT

Magnetic de-inking has been shown to be an efficient process for the removal of certain toner particles from mixed office waste (MOW) furnishes. It is possible to achieve a dirt removal of 96% with the WHIMS (wet high intensity magnetic separator) if all toner particles present in the furnish are at least paramagnetic. However, the recycled MOW has a variety of toner particles that vary from non-magnetic to ferromagnetic and , under these circumstance, it may be necessary to combine flotation with WHIMS in order to achieve a satisfactory level of dirt removal.

On the other hand, flotation may not be necessary if agglomeration of non-magnetic and magnetic toner particles can be accomplished. In this regard, conditions for toner agglomeration have been examined and the toner agglomeration characterized. Specifically, the magnetic susceptibility of such aggregates has been measured in order to facilitate efficient magnetic de-inking for wastepaper recycle mills.

INTRODUCTION

Magnetic de-inking of mixed office waste (MOW) is a very promising technique for the removal of toner particles for MOW pulp since most of the toner present in such a furnish has a certain magnetic character. Toner magnetic susceptibility varies from weakly paramagnetic to ferromagnetic depending upon the iron oxide content of the toner particles. Usually, the amount of iron oxide will range from 0 to 65% [1] depending upon the type of image development process used by the electrophotography machines [2].

Previous work [3] has shown that toner with at least a paramagnetic character can be successfully removed from MOW furnish by wet high intensity magnetic separation (WHIMS). For instance, it is possible to achieve a dirt removal of 97% in two-stages for a furnish made with toner containing only 30% iron oxide. This is a remarkable result when compared with the conventional de-inking processes which in order to accomplish the same extent of dirt removal, have to undergo diverse stages of flotation and/or washing. However, it is impossible to sort MOW according to the magnetic content of the toner particles. Consequently it is not expected that non-magnetic toners can be removed by magnetic separation. The magnetic heterogeneity of MOW toner particles can be overcome by combining magnetic separation with flotation. Such combination leads to a dirt removal of 92.7% [3].

Although these results seems reasonable, it would be more desirable to achieve complete toner removal by magnetic separation since, magnetic de-inking not only produces a high quality cellulose product but also improves the recovery of the fibers. Indeed, such a magnetic separation appears to be possible by agglomeration of the toner particles. It the agglomerates have sufficient magnetic susceptibility, it should be possible to remove them by WHIMS and thus eliminate the need for flotation and/or washing. In this regard, the magnetic susceptibility of toner agglomerates has been examined in order to consider the potential use of magnetic de-inking as a process strategy for recycle mills.

EXPERIMENTAL

Material

Toner in their pure state and as printed on paper were used to study agglomeration phenomena including size enlargement and magnetic susceptibility. Toners used for a photocopy machine (Xerox 5052 containing 0 percent iron oxide) and for a laser printer (EP-S Canon containing 30 percent iron oxide) were used in this research program.

The agglomeration of toner particles was achieved with two reagents, 1-octadecanol (MP 60°C) and a commercial reagent from Shell, Nonatell 1105 (MP 9.4°C) of unknown composition.

Agglomeration

Pure toner

Prior to agglomeration, the pure toner particles were cured and ground as described by Small [4] in order to simulate the same morphology of toners which are released from wastepaper during the pulping, that is, toner with flat shape and broad size distribution.

The agglomeration was performed in a 400 ml beaker with 200 ml of distilled water. The alcohol was added to the water and then the solution was stirred and heated to a temperature of 72°C and maintained at this temperature. The cured/ground toner particles were added and after 10 minutes of conditioning, agitation was stopped and the suspension allowed to cool in ambient surroundings. Subsequently, the beaker containing the agglomerates was quenched with cold water and filtered. The agglomerates were stored f or analysis.

The amount of toner and alcohol used in these experiments was based on a fictitious 3% fiber consistency. In the case of the cured toner the amount used was fixed at 1% of the fictitious dry fiber. On the other hand, the amount of alcohol was varied between 0.5 and 2% of the fictitious fiber. The amount of alcohol was selected based on the fixed amount of toner. For example, 1% alcohol represents the condition under which the agglomeration was achieved with an equal amount of toner and alcohol.

MOW furnish

A quantity of 250 grams of wastepaper (125 grams photocopied paper and 125 grams laser printed paper) were pulped under moderate agitation in the presence of hot steam (84 to 90°C) and deionized water for the release of the toner particles. The consistency of the pulp was proximately 12% by weight and subsequently the pulp was diluted to, 3% consistency for the agglomeration experiments.

One liter of the diluted pulp, under moderate agitation, was heated to a temperature of 72°C and than the alcohol was added at amounts that ranges from 0.5 to 2% on a dry fiber basis. After 30 minutes, the agitation was stopped and the pulp was quenched to room temperature. Subsequently, the cooled pulp was magnetically de-inked by WHIMS.

Wet high intensity magnetic separation (WHIMS)

A batch type wet high intensity magnetic separator, model 3X4L from Carpo was used to separate magnetic toner agglomerates from the non-magnetic cellulose fibers. The principle of operation has been described in the literature [5,6]. A liter of MOW pulp was fed slowly into the chamber containing a ferromagnetic matrix (steel balls) in-place after the coil current was set at the desired level. Magnetic toners are retained in the chamber after flushing with water while non-magnetic cellulose fiber is washed through the chamber. The magnetic toner particles were washed from the ferromagnetic matrix after the coil current was turned off.

The WHIMS unit was operated with soft iron balls, 19 mm diameter. The pulped wastepaper was fed continually in to the WHIMS at a consistency of 1%. Both fractions magnetic (toner agglomerates) and non-magnetic (cellulose fiber) were collected filtered and stored for analysis.

Magnetic susceptibility

Magnetic susceptibility of the agglomerates was measured using a Susceptomer Kappabridge that makes use of alternating current method [5]. The susceptometer has excellent accuracy, rapid measuring rate, and is able to determine magnetic susceptibility of materials that range from diamagnetic to ferromagnetic. The measurement yields kappabridges units that are normalized to a specific mass magnetic susceptibility (χ_g).

Image analysis

A PC-based image analysis system developed at the University of Utah [7] was used to measure the cleanness of the cellulose fibers. The measurement was done by placing a hand sheet of the product to be examined beneath a high resolution video system to capture and to digitize the image from the microscope. The image is transmitted to a microcomputer and analyzed by the software following the TAPPI standardized procedure for dirt removal.

SEM analysis

The scanning electron microscope was used to determine the distribution of iron oxide in the agglomerates and also to examine the morphology of the agglomerates.

RESULTS AND DISCUSSION

Magnetic Susceptibility of Toner Agglomerates

It is essential for magnetic de-inking that the toner agglomerates have sufficient magnetic character to be successfully removed from the non-magnetic cellulose fiber. At least a paramagnetic state is required in order to overcome competing forces (drag and gravitational forces) that act against the magnetic force during the magnetic separation.

During the process of agglomeration toners of different magnetic character are randomly assembled. Therefore, the magnetic susceptibility of an agglomerate will depend upon the combination of the individual toner particles present in the agglomerate. In other words, how may toner particles of strong magnetic behavior should be present with weak magnetic toner particles in an agglomerate to make this agglomerate at least paramagnetic.

To estimate the magnetic susceptibility of an agglomerate, a theoretical calculation was made for an agglomerate made of weakly paramagnetic toners from a photocopy machine and ferromagnetic toners from a laser printer having 0% and 30% iron oxide respectively. The magnetic susceptibility of agglomerates of various compositions were then calculated and the results are reported in Table I. As can be noted, the magnetic susceptibility of the agglomerate increases significantly as the agglomerate becomes richer in ferromagnetic toner.

How will the agglomerates behave during WHIMS? Will the size of the agglomerates effect the separation efficiency? The answer to these questions can be predicted by comparing the calculated forces (magnetic, drag and gravitational) which at on the agglomerate during WHIMS. Figure 1 shows the results for agglomeration of different toner composition passing through a theoretical magnetic field induction of 2T, at a velocity 0.1 m s^{-1} with the field gradient generated by a matched steel ball matrix.

As the results show, for typical agglomeration from 1 to 3 mm in size the magnetic force completely overlaps the drag forces. In other words, it is theoretically possible to achieve the removal of agglomerates having a composition of at least 20% ferromagnetic toner. In order to determine the actual composition of the agglomerates prepared experimentally, the agglomerates were analyzed by SEM. Figure 2 shows a typical agglomerate toners with Nonatell 1105. Toner particles in the agglomerate having a smooth surface are the photocopy toners with 0% iron oxide (weakly paramagnetic) while the toner particles having a rough surface represent the laser printer toners with 30% iron oxide (ferromagnetic). As can be noted, there is a good distribution of the ferromagnetic toners in relation to the weakly paramagnetic ones. Therefore, it is expected that magnetic de-inking of an agglomerated toner particles should be possible.

MOW Magnetic De-inking

If the toner particles are not agglomerated, it is only possible to achieve a dirt removal of 51% from MOW furnish for a single-stage of WHIMS as shown in Figure 3. In this case, the magnetic de-inking is inefficient due to the fact that only 50% of the toner particles in the furnish has enough magnetic susceptibility to be removed.

Figure 3 also shows the results from a single-stage of WHIMS for furnishes in which the toner particles were agglomerated. In these particular experiments, agglomeration with Nonatell 1105 leads to a dirt removal of 82.3% while agglomeration with 1-octadecanol leads to a dirt removal of 90.8%. In either case, it is clear that agglomeration indeed improves the removal of toner particles with gain of almost 40% in the extent of dirt removal.

The difference between the results for the two agglomeration reagent can be related to the fact that the Nonatell 1105 has a low melting point, 9.4°C. after the furnish quenching the Nonatell 1105 still remains in the liquid state and this leads to weaker agglomerates that can be broken. Also it should be mentioned that Nonatell 1105 is a reagent designed as a flotation aid and was not designed as an agglomerate reagent for magnetic separation.

In the case of 1-octadecanol, a straight chain alcohol with melting point at 60°C, separation of the agglomerates is improved because after quenching the alcohol solidifies with toner particles. This makes a rigid agglomerate, significantly stronger, which facilitates its recovery by magnetic separation.

CONCLUSION

Calculations from first principles suggest that agglomerates containing at least 20% ferromagnetic toners are required for an efficient separation by wet high intensity magnetic separation (WHIMS).

For the first time it has been demonstrated that magnetic de-inking can successfully be used to remove both magnetic and non-magnetic toners by appropriate agglomeration of these toner particles. After agglomeration a single-stage dirt removal of almost 91% can be achieved by wet high intensity magnetic, such a process should be of industrial significance and could eliminate the need for extensive flotation and/or washing in the treatment of MOW furnishes.

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Table I. Theoretical Magnetic Susceptibility for Toner Agglomerates*

Agglomerate, percent ferromagnetic toner	Specific (Mass) Magnetic Susceptibility (m^3/kg)
0 %	$1.40x10^{-8}$
10%	$1.74x10^{-5}$
20%	$3.49x10^{-5}$
30%	$5.23x10^{-5}$
40%	$6.97x10^{-5}$
50%	$8.71x10^{-5}$
60%	$1.05x10^{-4}$
70%	$1.22x10^{-4}$
80%	$1.39x10^{-4}$
90%	$1.57x10^{-4}$
100%	$1.74x10^{-4}$

* Agglomerates prepared as mixture of Xerox 5052 (0% iron oxide) and Canon EP-S (30% iron oxide)

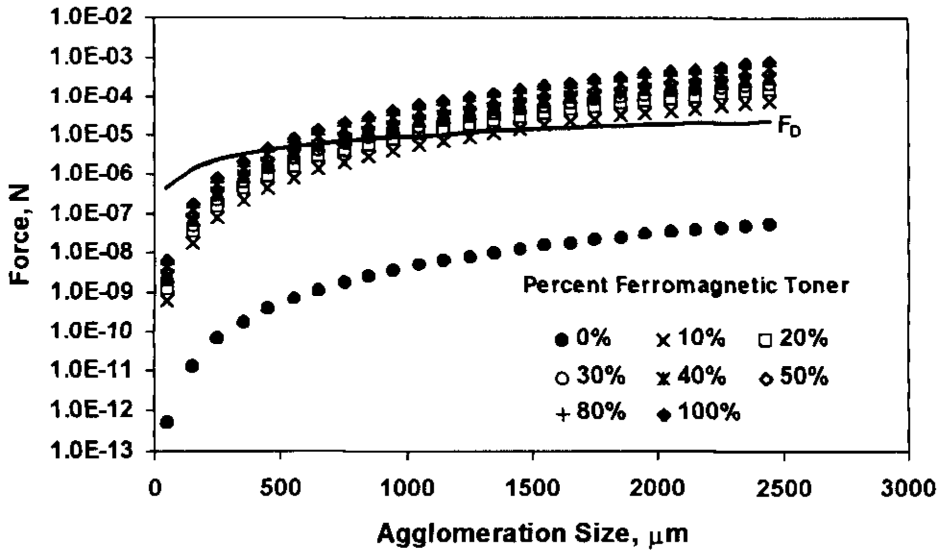


Figure 1. Plot of magnetic force and drag force (F_D) versus agglomerate particle size for agglomerates flowing through the steel ball matrix placed in a magnetic field of 2 T at interstitial velocity 0.1 m/s. Agglomerate composition by percent of ferromagnetic toners.

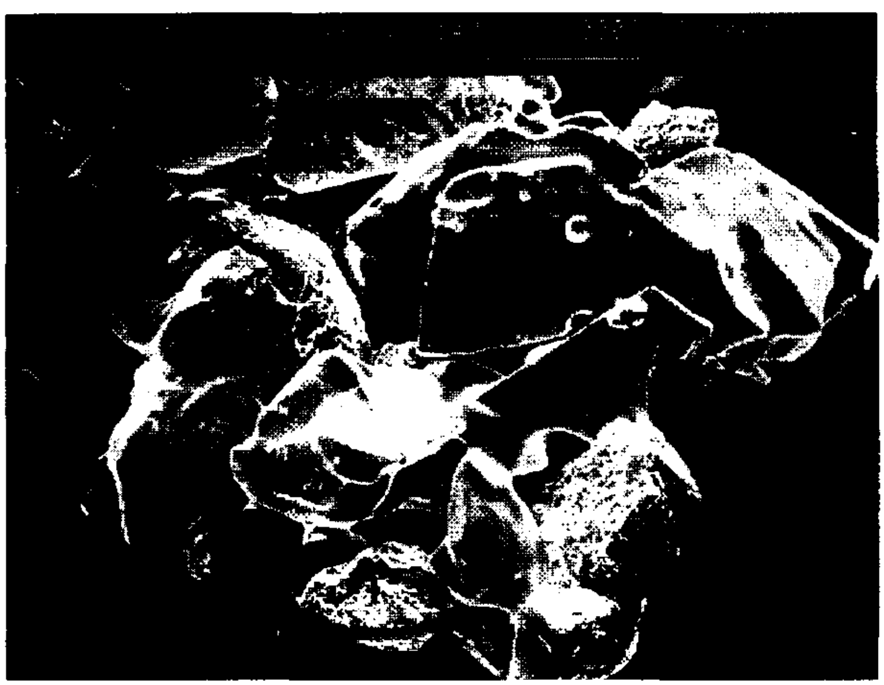
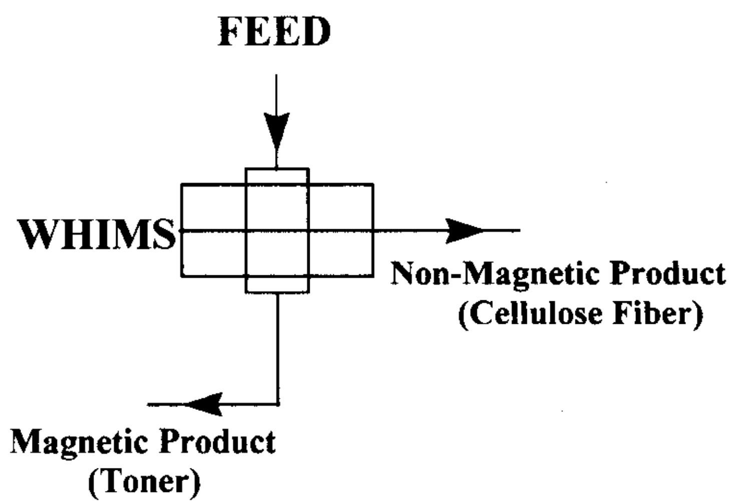


Figure 2. Agglomerate of toner particles of 0% iron content(smooth surface) with toners with 30% iron oxide content (rough surface). The agglomeration was done at 72°C with Nonatell 1105.



MOW Feed	Dirt Removal*
Dispersed Toner (no reagent)	51.0 %
Agglomerated toner (Nonatell 1105 - 2% dry fiber)	83.2 %
Agglomerated toner (1-octadecanol - 2% dry fiber)	90.8 %

$$^{*}\ \text{Dirt Removal} = 100\left(1 - \frac{\text{Area covered by ink after treatment}}{\text{Area covered by ink before treatment}}\right)$$

Figure 3. Single Stage WHIMS for mixed office wastepaper (50% Laser printer + 50% photocopy). Ferromagnetic matrix, 19 mm steel balls and a magnetic field of 0.3 T.