# A LABORATORY MEASUREMENT METHOD FOR PRESSURE SENSITIVE ADHESIVES IN AGGLOMERATION DEINKING OF MIXED OFFICE WASTE PAPER: THE HIGH-LOW SCANNING CONTRAST METHOD

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A simple measurement method for pressure sensitive adhesives (PSA) in an agglomeration deinking system of mixed office waste paper was studied. This method was based on the different scanning performance of ink and PSA specks in hot-pressed and oven-dried handsheets with the change of contrast values that had been selected and set in the image analysis software. The numbers of ink specks per square meter (NPM) were well recognized at both low and high contrast values and exhibited a very good linear relationship within a range of contrast values. The PSA specks, on the other hand, could not be recognized at the low contrast values and could only be recognized at high contrast values. The NPM value of the ink specks was found to have the highest values at the high contrast values and could be accurately predicted by its NPM value at the low contrast values. Thus, the NPM value of the PSA specks could be easily calculated by the total NPM of the handsheet at the high contrast value minus the projected NPM of the ink specks from its low contrast conditions. Compared to the dye method, which was also used on the measurement of microstickies, this method is suggested as a simple and quick laboratory tool to measure the relative quantity of PSA in the mixed office waste paper with minimum interference from the residual toner ink.

*Keywords: Measurement method; Pressure sensitive adhesive; Ink; Paper recycling; Contrast*

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## INTRODUCTION

To use waste paper as the raw material for papermaking has long been important for both developed and developing countries for environmental and economic reasons. Among waste papers, office waste paper is a major grade of recycled paper for bleached fiber reutilization. However, the utilization of this type of waste paper frequently introduces contaminants to the recovered secondary fiber. Of all these contaminants, toner ink and PSA are two types that are difficult to remove from the system. Although toner ink is difficult to remove with high efficiency, the remaining ink will only affect the visual quality of the product, and this ink contaminant can still be removed via the modern deinking process to meet quality requirements. But the complete removal of sticky contaminants still remains a challenge for most deinking paper mills (Oldack and Gustafson 2005).

Sticky contaminants, which are commonly detected as deposits on paper machines and in paper products, have been summarized and classified as adhesives, hot

melts, coating binders, ink residues, deinking chemicals, wood resins, and wet strength resins (Douek 1997). These sticky contaminants will accumulate in the recycling system. When the physical or chemical conditions change, the sticky materials will be deposited on wetted surfaces within the paper machine system, giving rise to operational problems such as paper web breaks and an increase in paper machine down time. The residual stickies will also cause faults in the paper such as spots or holes in the sheets, reducing product quality (Blanco *et al.* 2007; Monte *et al.* 2004).

Among these sticky materials, pressure sensitive adhesives make up the majority of the sticky contaminants in mixed office paper, stemming mostly from labels used in the office paper. PSA products are deformable and elastic during recycling, which contributes to low removal efficiency in screening operations. Also, the specific gravity of PSA materials is often close to one, which leads to difficulty of removal by cleaners (Scholz 1993).

Stickies are usually classified into levels based on their size: macrostickies, microstickies, and disco (dissolved and colloidal) stickies. Macrostickies are those retained on 0.006 inch (0.15 mm), 0.004 inch (0.10 mm), or 0.003 inch (0.075 mm) laboratory slotted screens. Microstickies are those accepted by 0.006 inch, 0.004 inch, or 0.003 inch laboratory slotted screens. Disco stickies are those smaller than 0.005 mm. In addition to size, stickies can be sub-classified into primary stickies and secondary stickies (Doshi 2009).

Galland *et al.* (2009) sub-classified and mapped stickies throughout the deinking process. The sub-classification and mapping demonstrated that small macrostickies are poorly removed by the fine screen, which is responsible for heavy deposits in some cases. The results showed that these mini-stickies originated primarily from PSA, which can be present in large quantities in poorly sorted office furnish. Sarja *et al.* (2006) found that most stickies in deinked pulp are very small and are not dissolved or colloidal. The majority of residual stickies are thus microstickies. Because stickies cause major operational problems, the detection and control of stickies have long been industrial priorities. Although no one method can measure the residual stickies in the recycled pulp at one hundred percent accuracy, many quantification methods have been proposed.

Sithole and Filion (2008) assessed different methods of measuring macrostickies by using pulps with sticky contaminants. It was suggested that there was no absolute method for ascertaining the area of the contaminants, as the parameter was subjected to sample processing conditions, especially the duration, temperature, and pressure applied to them. Microstickies are generally quantified by measuring the accumulation of tacky contaminants that adsorb onto a hydrophobic collector suspended in the contaminated pulp. These methods have frequently been used to quantify both the microstickies and the dissolved and colloidal sticky materials. Doshi *et al.* (2003) compared eight methods of measuring microstickies. A conclusion was thus drawn that the different processes of each method lead to measurements of residual stickies of different size ranges. Furthermore, only a relative quantitative comparison for each method, together with a specified waste paper grade, was valid.

Although there are many methods of quantifying stickies in office waste paper, some methods, such as solvent extraction and pulp deposition, are rather tedious. In an attempt to simplify the quantification, researchers have tried to utilize image analysis technology by magnifying the contrast between stickies and the background materials in order to differentiate and measure the sticky materials. The Image Analysis method is

based on the contrast between stickies, ink specks, and the background. Several methods have been developed, namely, INGEDE (Ackermann *et al.* 1998), the PMV method (Doshi *et al.* 2003), the TAPPI method (Heise *et al.* 1999), and the laminator method (Aquan-Yuen *et al.* 1998), to reveal or enhance the contrast. Moreover, Morplas Blue 1003, a nonplar organic dye that can preferentially stain hydrophobic materials, is commonly used to dye sticky materials to enhance the contrast between fibers for micro-sticky or macrosticky measurements. (Aziz and Rosenberger 1997; Blais *et al.* 1997; Lucas *et al.* 2001).

From all previous work, it can be concluded that the image analysis method can be applied to both macro- and microsticky measurements. This method can also be applied to measure residual PSA in deinked office waste pulp. However, the interference between residual ink and PSA is rarely discussed. Furthermore, some of the methods are rather tedious.

Thus, it was of interest to develop a simple method to measure the residual sticky (PSA) materials in the deinked office waste pulp regardless of the presence or absence of non-impact toners. In this study, PSA, which are the major sticky materials in office waste paper, were used as the sticky material of study. Laser toner printed copy paper was used as the recycled office waste paper, and laser toner was used as the ink source. The hope was to develop a simple PSA measurement method that could recognize the residual stickies, especially with the presence of residual ink in the screened deinked pulp, with reasonable reliability.

As is well known, agglomeration deinking is one of the efficient methods for office waste paper deinking (Borchardt *et al.* 1997; Azevedo and Miller 2000). Thus, this High-Low Scanning Contrast Method (HLCDM) was tested in a laboratory agglomeration deinking experimental system, which comprised printed toner ink, PSA labels, and 1-octadecanol as the agglomeration agent (Jiang *et al.* 2012; Wang *et al.* 2011). Moreover, the results were compared with the dye method.

## EXPERIMENTAL

### Materials

The copy paper used in the study was a commercial product provided by APP Co., China, and the paper was printed with an HP-1010 LaserJet printer using its original toner. The pattern printed on every piece of paper was always the same.

The PSA was generated from a commercial labeling paper that was supplied by Zhuosheng Office Materials Company, China. More details of the materials are listed in Table 1.

The three kinds of pulp that were used to develop "the High-Low Scanning Contrast Method" were made separately. Pulp A was made directly from blank copy paper without any printing or PSA. Pulp B was made from HP-1010 laser toner printed (8% of the total surface area) copy paper without PSA. Pulp C was made from non-printed copy paper but with 4% PSA labels in OD weight based on the paper. The labels were pasted onto each piece of copy paper at the same location and sealed in a plastic bag overnight for use. Before the pulping experiment, these papers were cut into 1.5 mm-wide strips by scissors. Both the printed paper and the non-printed paper without PSA were torn into 1 cm × 1 cm pieces before pulping.

**Table 1.** List of Materials

| Materials | Names (or grades) | Source |
|---|---|---|
| Paper | "Gold Flag Ship" copy paper, 70g/m$^2$, AKD sized | APP Co., China |
| Toner | Cartridge Q2612A for HP1010 LaserJet printer Styrene/acrylate copolymer based toner | Hewlett-Packard Company, CA, USA |
| Pressure sensitive adhesive label | Polyacrylate based PSA | Shanghai Zhuosheng Office Materials Co., Ltd |
| 1-octadecanol | Pure Chemical | Shanghai Jiuyi Chemical Reagent Co. |
| n-heptanes | Pure Chemical | Sinohere Chemical Reagent Co., Ltd |
| Dye | Morplas Blue 1003 | Hangzhou Yuhao Chemical Technology Co., Ltd |

A 1.0 L homemade stainless-steel cylindrical type pulper (10 cm diameter) with a helical rotator was used for pulping. The rotator was adjusted with a variable-speed controller. Before pulping, 400 mL of distilled water was added into the pulper, and then the distilled water was heated to 70 $^{o}$C by a temperature controlled water bath kettle that was set under the pulper; 30 g (OD) of paper was put into the pulper. During the pulping process, the rotator speed was controlled at 800 rpm for an hour. At the end of the pulping, the pulp was transferred to a plastic bag and cooled down by tap water.

As for the agglomeration pulping which was used to test "the High-Low Scanning Contrast Method", 0.5% 1-octadecanol on OD paper, a highly effective agglomeration agent (Chang *et al.* 1996; Chen *et al*. 2004; Wang *et al*. 2011; Jiang *et al*. 2012), was added to the bath of pulper with 400 mL of water, which was heated to 70 $^{o}$C and mixed at 300 rpm for 3 minutes to ensure that the 1-octadecanol was molten. Then 30 g (OD) of paper, with fixed printed toner inks and different amount of PSA labels, was added. The pulper was run at 800 rpm for pulping in the first 30 minutes, and then the rotor was slowed to 450 rpm for agglomeration for another 30 minutes. At the end of the pulping, the pulp was transferred to a plastic bag and cooled down by tap water.

## Screening

After pulping, the pulp slurry was transferred into a 0.15 mm slotted laboratory screen with pressure control. The screening process was kept at 0.5 bars for about 8 min until there was no fiber on the screen plate. The accept was collected into a 500-mesh double-layer fabric bag which could retain fiber, ink, and PSA particles. This screening procedure was conducted on all the pulp slurry in the experimental study.

## Handsheet Preparation

Six handsheets of 60 g/m$^2$ were made according to the ISO 5269-2 method with a PTI Rapid-Köthen sheet former. The handsheets were dried in the handsheet dryer attached to the device as soon as they had been formed. On the bottom side of the drier are copper wires and on the upper side is a removable cover through which 93 $^{o}$C water was circulated. Before drying, the wet handsheets were placed between two dry fabric blankets. During the drying, the sandwiched handsheets were placed on the copper wires, and the upper side was covered against the rubber mylar at the bottom side of the

removable cover. Then, from the bottom side of the copper wire a vacuum was created by a vacuum pump, generating 1.0 bar of pressure onto the handsheets. The drying process was maintained for 5 min.

### Dyeing of Handsheets

Selected handsheets were dyed with Morplas Blue 1003, which would preferentially stain the adhesives a blue color and enhance the contrast between the fiber and the PSA. The preparation of the dyeing solution and the dyeing process were conducted according to a previous method (Lucas *et al.* 2001). A mass of 0.67 g of Morplas Blue 1003 was diluted with 1000 mL of heptanes in a glass beaker. The solution was stirred overnight at room temperature with a magnetic stirrer. The solution was then filtered by filter paper in a Buchner funnel. The filtered dye solution was collected into a 1000 mL flask. The filtered dye solution of 250 mL was poured into a stainless basin. Each handsheet was submerged into the dye solution and swirled for ten seconds. The handsheets were then removed with forceps and hung on a string with a binder clip. The handsheets were allowed to dry overnight at constant room temperature and humidity. The next day, the handsheets were removed from the string. 500 mL of heptanes was poured into a stainless dish. Each handsheet was submerged in the heptanes solution and swirled for ten seconds. The handsheets were removed with forceps and hung from a string with a binder clip. The handsheets were removed when they were dried.

### Scanning

A Founder T35 scanner was used to scan the handsheets. The handsheets were placed on a translucent glass pad and then covered with a non-translucent black cover pad. A light bulb under the glass pad was turned on during scanning. Hence, when a translucent speck was scanned, it was recorded in black or grey. The scanner records areas that are a different color from the white fiber. The image analysis software that was used was Autospec V4.0 Image Analysis System (State Key Laboratory of Pulp and Paper Engineering; South China University of Technology), which could set the scanning conditions, including brightness, contrast, resolution, and size range of detected specks. The brightness value was set at 46 (ranging from 0 to 100), and the resolution was set at 600 dpi. The contrast value range was also from 0 to 100. Here, to distinguish the original contrast between the contaminant stains and the background fibers, the contrast value set in the image analysis software was called the "scanning contrast value" or "contrast value". The original contrast between the contaminant stains and the background fibers was called "inherent contrast". The size range of specks detected was set from 0.01 $mm^2$ to 10 $mm^2$. Each handsheet was scanned on both sides, and the sum of the values of each side was used for one handsheet. A total of six handsheets were measured, and the average value of the six handsheets was used as one data point.

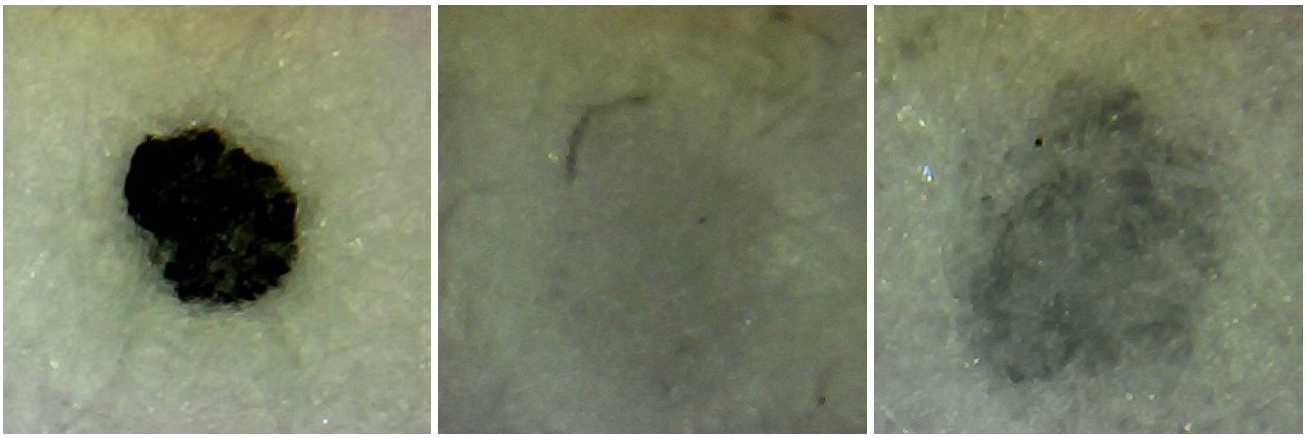
## RESULTS AND DISCUSSION

### Characteristics of Ink and PSA in Handsheets with Different Fully Opaque Background Pads

The handsheets prepared from pulp slurries, which consisted of laser-printed ink (Pulp B) and PSA pulp (Pulp C) separately, were observed with a microscope. Since all

of these handsheets were dried at 93 $^{o}$C at a pressure of 1.0 bar, the ink and PSA particles were pressed flatter and appeared larger than when they were in the pulp slurry. This was especially notable in the case of the PSA particles, which became translucent. Figure 1 (a) is a photo of laser-printed ink in the handsheet that was photographed with the black, fully opaque background pad. Figures 1 (b) and (c) are PSA in the handsheets with different opaque backgrounds.

As shown, the ink speck in (a) is a dark black spot surrounded by white fibers. Evidently, the contrast between the ink speck and the background was very high, and the scanner would be very sensitive to this type of stain. The handsheet (b) was placed on a white opaque pad, and the PSA speck was almost the same color as the background paper. The handsheet (c) was placed on a black opaque pad and the color was darker than (b). As the black opaque pad could facilitate the recognition of PSA specks in an oven-dried handsheet, it was chosen as the top pad for scanning.



(a) (b) (c)

**Fig. 1.** Photos of the ink and PSA specks in handsheets

## Effect of Scanning Contrast Value on Ink and PSA Specks

In order to understand the sensitivity of the scanning contrast values to ink and PSA specks, three types of handsheets were scanned with the Founder T35 scanner under different contrast values varying from 15 to 70. The first type of handsheet was made from Pulp A (blank paper). The second type of handsheet was made from Pulp A with 2% Pulp B (laser toner only). The last type of handsheet was made from Pulp C (PSA only). The results are shown in Fig. 2.

As shown in Fig. 2, the maximum NPM value of all three types of handsheet occurred at about contrast 55. When the contrast value was lower or higher than 55, the NPM values decreased. This can be explained in that a suitable contrast value facilitated the recognition of the specks, which magnified the color difference between the fiber and the specks of ink or PSA. Excess low or high contrast value would render the specks of ink and PSA obscure. It should be noticed that the NPM of the blank paper was not zero and that it changed throughout the contrast values. The NPM at contrast 55 was around 4200. It actually resulted from the shading interference of the blank copy paper.

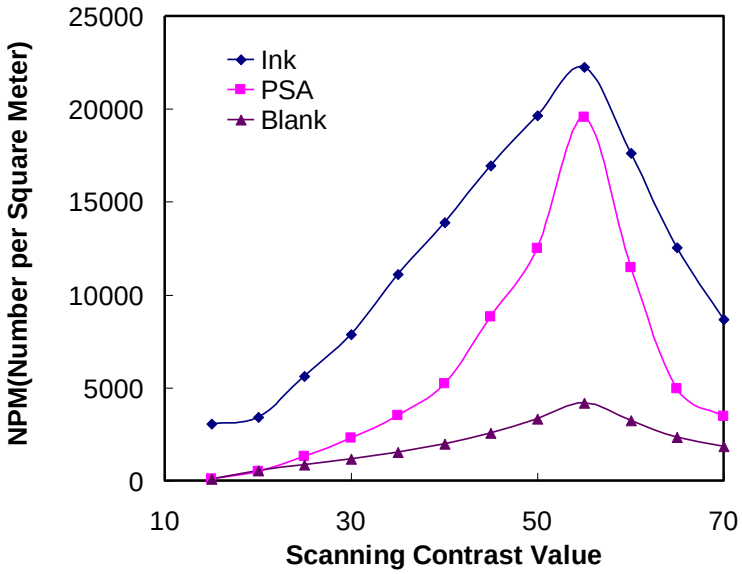



**Fig. 2.** The effect of the scanning contrast value on the NPM of the ink and the PSA specks

However, when the contrast value was very low (10 to 20), the NPM value of the PSA was close to 0, while the NPM value of the ink specks remained at about 4000. This meant that most of the PSA specks could not be recognized at the low contrast value, but that a large portion of ink specks could be recognized. It can be concluded that ink and PSA perform differently at low scanning contrast values, which stems from the inherent contrast differences between the particles and the backgrounds. The PSA specks were grey and unrecognizable at low contrast values, when it was lower than 20, whereas the ink could be recognized at low contrast values because the ink specks were black and had higher inherent contrast with the white fibers. It was also interesting to find that the NPM value of the ink specks had a linear relationship with the contrast values between 20 and 55.

Since both the PSA and the ink specks had the highest NPM value at the contrast 55, this value was chosen to reflect the maximum value of both the ink and PSA specks (high contrast value), while the contrast of 20 (low contrast value) was chosen to reflect a low NPM value of ink and a value where the NPM of PSA was almost zero.

## Sensitivity of NPM to Ink and PSA at Low and High Contrast Values

The high and low contrast values (55 and 20) were used to measure both the ink and the PSA specks in the pulp slurry. Additionally, two more contrast values of 15 and 25 were used to measure the ink and PSA specks for further comparison. The results are shown in Fig. 3.

As shown in Fig. 3 (a), the handsheets were made from combinations of Pulp A and Pulp B, and there was a 5% increment of concentration of Pulp B in the combinations. Each handsheet was scanned at four different contrast values. The NPM of the ink specks at all contrast values increased with the increase in the quantity of ink, and these were in good liner correlation ($R^2$>0.99) with the amount of Pulp B, which indicated that NPMs of all contrast values were appropriate for reflecting the relative quantity of ink specks in the handsheets.

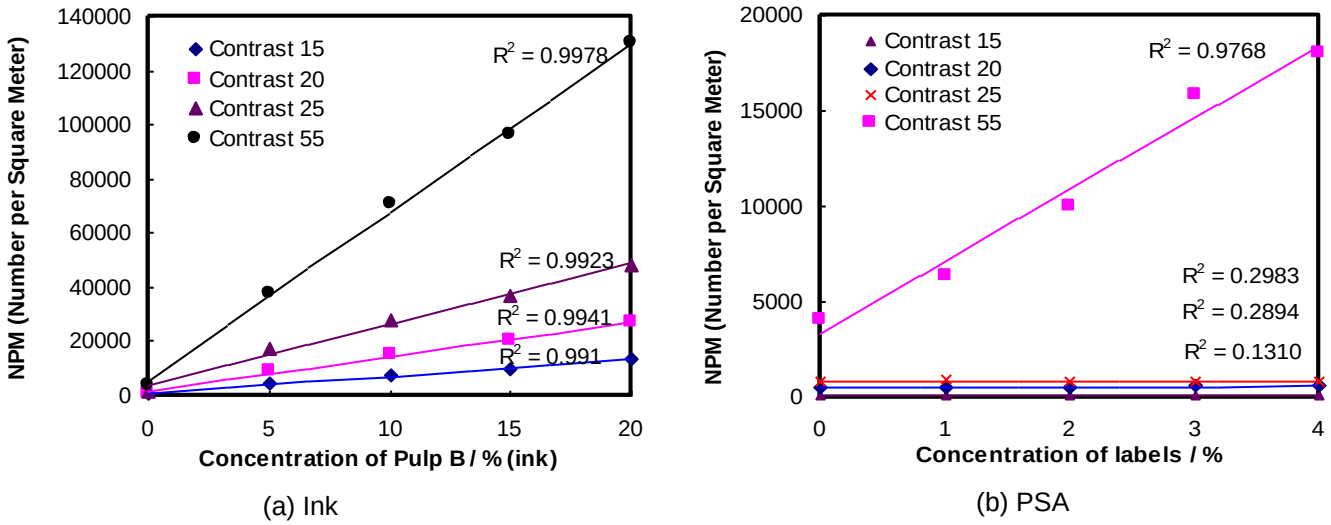



**Fig. 3.** NPM of the two types of handsheets at high and low scanning contrast values

In Fig. 3 (b), the handsheets were made from combinations of Pulp A and Pulp C, and there was a 25% increase of concentration of Pulp C in the combinations, which is equivalent to 1% increments in PSA labels. As shown in Fig. 3 (b), the NPM values of PSA at contrast 55 was in good liner correlation ($R^2$>0.97) with the amount of PSA. However, the NPM values changed very little at low contrast values of 15, 20, and 25. The NPM value measured at low contrast actually resulted from its inherent shading interference from the blank copy paper. The results indicated that the NPM at contrast 55 could be used to reflect the relative amount of PSA specks in the handsheet.

It should be noticed that the NPM of the handsheets without any contaminant was not zero in Figs. 3 (a) and (b). So the NPM interference effect from the blank paper was always present and was affected by both the brightness value and the contrast value. For example, the intercept of the zero points of ink and PSA at contrast 55 was around 4000, and the intercept of the zero points of ink and PSA at contrast 20 was around 500. The good thing is, the interference could be eliminated by the actual total NPM minus the predicted NPM of ink at the same contrast of 55 using this method. A more detailed description will be addressed later.

## Relationship between NPM of Ink at Low and High Contrast

As shown in Fig. 3 (a), it is clear that the NPM of the ink specks at each contrast value was in good linear correlation ($R^2$>0.99) with the concentration of Pulp B, which indicates that there should exist a good linear relationship between the NPM at low and at high contrast values. To establish the relationship between NPMs at low and at high contrast values, Fig. 3 was redrawn as Fig. 4.

As shown in Fig. 4, the horizontal coordinates are NPMs scanned at the low contrast value of 20, and the vertical coordinates are NPMs of the same handsheets scanned at the high contrast value of 55. There is also a good linear correlation ($R^2$=0.9971) with various amounts of ink toners.

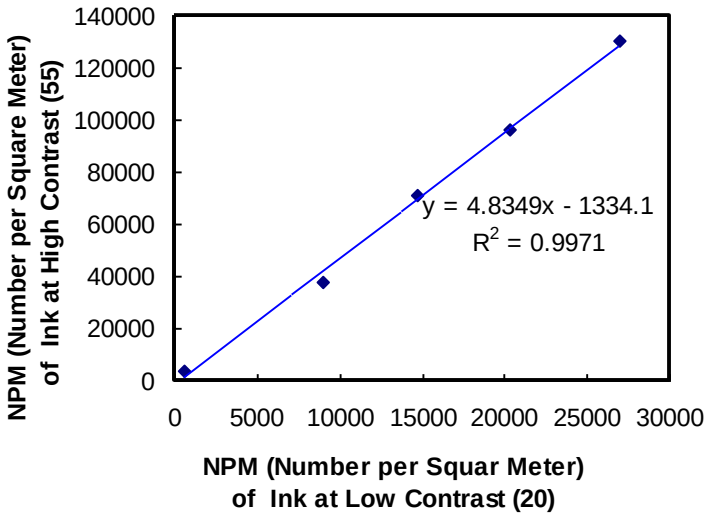



**Fig. 4.** The relationship between the NPM of ink at low and at high contrasts

Therefore, the NPM of ink specks at high contrast value can be predicted by the NPM at low contrast value from the following equation.

$$NPM_{55} = 4.8349 \times NPM_{20} - 1334 \quad (1)$$

## The Measurement Method of Ink and PSA in the Pulp

It has been revealed that ink and PSA have different inherent contrast in the background of the handsheets, and the scanning results performed differently with the change in scanning contrast.

At the contrast level of 55, both the PSA and the ink specks were well recognized, and their NPM reached the maximum value. It was thus revealed that the contrast value of 55 could be used to quantify the PSA and ink specks in the handsheets. However, a portion of the ink specks was recognized at the contrast of 20, whereas the PSA specks were not recognized at this contrast value. The contrast value of 20 could be used to quantify the relative amount of ink specks, and the NPM of the handsheets at contrast 20 is an indication of the amount of ink specks alone.

Moreover, a good linear correlation exists between the NPM of ink specks at contrasts of 55 and of 20. The NPM of ink specks at contrast 55 could be predicted from the NPM at a contrast of 20 with good accuracy. The NPM of the PSA specks could be computed as the total NPM at contrast 55 minus the NPM of ink specks that was predicted from the NPM at contrast 20. This method was called "the high-low scanning contrast method" accordingly.

The high-low scanning contrast method for PSA could further be expressed by the following equations:

NPM of ink at contrast 55 (predicted) = 4.8349 × NPM at contrast 20 – 1334 (2)

NPM of PSA at contrast 55 = NPM at contrast of 55 (actually measured total NPM) -NPM of ink at contrast 55 (predicted) (3)

It should be noted that as the handsheet has been hot pressed, the particle sizes of the ink or PSA speck cannot actually reflect their real size by use of this method.

## Application of the High-Low Scanning Contrast Method to Mixed Pulp with PSA and Non-Impact Toner

To demonstrate and evaluate the high-low scanning contrast method, the method was applied to copy paper pulp mixed with non-impact toner and PSA (Pulp A mixed with Pulp B and Pulp C at the same time). The results are shown in Fig. 5. In the horizontal coordinates, P stands for the PSA labels and I for ink (Pulp B). There was a 1% increase in PSA labels for each 0.5% decrease in Pulp B in the mixed pulp. The predicted NPM of the ink at contrast 55 was calculated by the NPM at contrast 20 according to the described equation. The NPM of PSA is the total NPM of the handsheet minus the predicted NPM of the ink.

As shown in Fig. 5, the NPM values of ink decreased as Pulp B decreased, and the NPM values of ink were in good liner correlation ($R^2$>0.98) with the amount of Pulp B. The NPM values of PSA increased with the increase in the concentration of PSA labels and were in good liner correlation ($R^2$>0.99) with the concentration of PSA labels. This method could give relative values of PSA and ink, respectively.

However, it should be noticed that the NPM of ink was 6000 rather than zero, in the case of the handsheet with 4% PSA labels and 0% ink, which was predicted from the NPM at contrast 20. This could be explained by the fact that that the blank copy paper has its inherent shading effect. The NPM that resulted from the shading effect at contrast 55 was about 4000 in Figs. 2 and 3. The NPM value obtained directly from the scanning includes this portion. The difference existed between the actual value (3800 to 4200) and the predicted value (6000) of the NPM that resulted from the shading effect at contrast 55. Although the blank paper shading effect was enlarged during the PSA calculation, in which the NPM value is a difference of two NPM values, the interference from the blank paper is actually eliminated. The NPM of the PSA is not affected by the NPM of the original blank paper in the high-low scanning contrast method. As shown in Fig. 5, in the handsheet with 0% PSA and 2% Pulp B, the NPM of the PSA was almost zero.

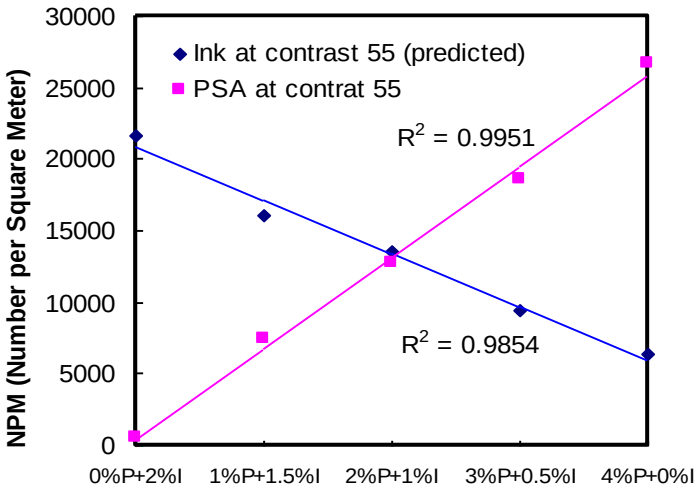



**Fig. 5.** NPM of the mixture of ink (I) and PSA (P) at different amounts

The NPM of the PSA of 2% labels and 1% Pulp B was about 12000 in Fig. 5, and without ink present the NPM was 10000, as shown in Fig. 3 (b). The NPM of the PSA was a little higher when ink was present. This might be explained by a phenomenon in a waste paper mill that the PSA are usually stained by ink or other dark contaminants, thus becoming darker and easier to recognize. In the mixing process, some of the PSA specks were stained by the ink. So, the NPM was higher. The NPM of the PSA by this method was only a relative value. However, the NPM value measured by this method still remained in a very good linear relationship with the actual added PSA, and could be used for the PSA quantification in the system which contains PSA and toner ink.

## Comparison of the High-Low Scanning Contrast Method to the Dye Method in the Agglomeration Deinking System with PSA

To further examine the efficiency and the applicability of the high-low scanning contrast method, the method was applied in a laboratory scale agglomeration deinking system to quantify the ink and the PSA. Additionally, the results were compared with the known dye method. In these experiments, the agglomerating agent of 0.5% 1-octadecanol based on 30g OD weight of printed copy paper was charged together with a fixed amount of blank copy paper and a fixed amount of laser toner printed ink (equivalent to a 7% amount of Pulp B), and various amounts of PSA labels. The pulping conditions were the same as those described on the pulping section above. The pulped slurry was screened with a 0.15 mm slot laboratory screen. The screen accepts were then used for analysis. The quantity of the PSA labels pasted on the printed copy paper changed from 0% to 4% by increments of 1%. The resulting PSA values measured by the high-low scanning contrast method are shown in Fig. 7.

It should be noted that, in the dye method, PSA materials are preferentially dyed blue. Thus, the inherent contrast between PSA and the background of fiber is enhanced. This method is usually used to analyze sticky materials contained pulp without ink and rarely considers the interference of the residual toner inks.

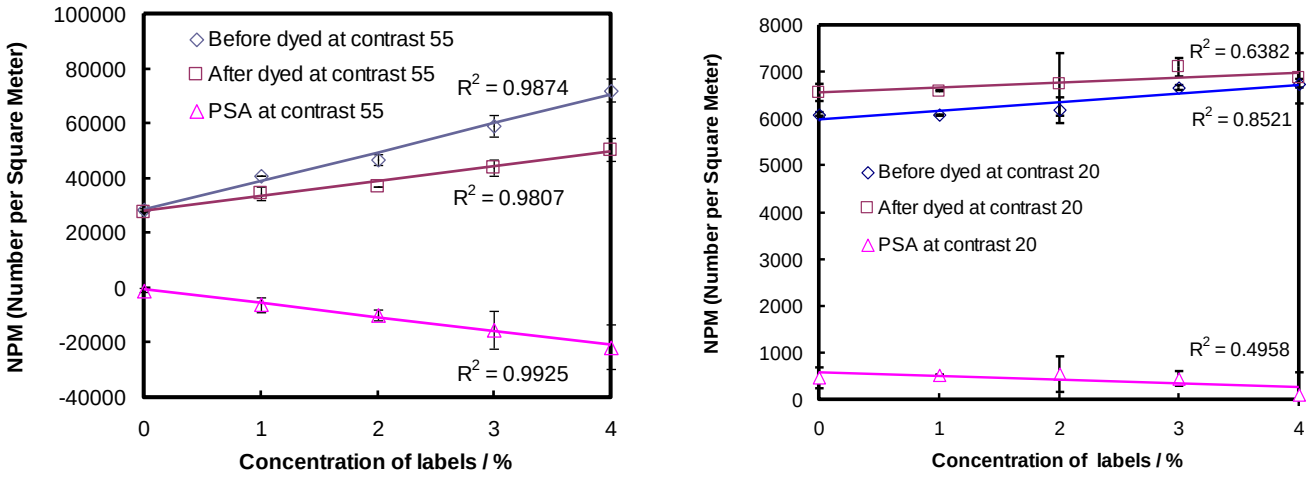



**Fig. 6.** Application of the dye method to agglomeration deinking system

For application of the dye method to the ink/PSA contaminants contained in the deinking system, a contrast value at which only ink specks are recognizable and PSA are unrecognizable was chosen before dyeing. As revealed in Fig. 2, the contrast value of 20 met this requirement and was chosen. Theoretically, the PSA specks would be recognizable after dyeing. The NPM value of the PSA is the measured NPM of the handsheets at contrast 20 after being dyed minus that before being dyed. The results are shown in Fig. 6 (a). As shown in the figure, the NPM of the handsheets at contrast 20 changed very little before and after dyeing through various concentrations of PSA labels and maintained a very narrow range of values. Moreover, the linear relationship between the NPM of the PSA and the dosage concentration of the PSA labels was very poor. This indicates that the preferentially dyed PSA specks could not be effectively recognized at the contrast of 20 and that it was impossible to accurately quantify the PSA specks at the low contrast of 20 with the interference of the existing ink.

It was suspected that the preferentially dyed PSA specks might be better recognized at a higher contrast value. So the high contrast of 55 in Fig. 2, at which all the stains in the handsheet were well recognized, was also used to quantify the PSA specks by the dye method. Again, the NPM value of PSA was the measured NPM of the handsheet at contrast 55 after dyeing minus that before dyeing. The results are shown in Fig. 6 (b). The NPM at contrast 55 of the handsheet before dyeing, which represented the total amount of the ink and PSA in the handsheet, increased with the increase in the concentration of the PSA labels and showed a good linear relationship ($R^2$>0.98) with that concentration. The NPM after dyeing at contrast 55 also showed a good linear relationship ($R^2$>0.98) with the concentration of the PSA labels. However, the NPM value became smaller after dyeing, indicating that some contaminant specks could not be recognized after dyeing. This actually resulted from the background of the fiber being somehow dyed so that the inherent contrast between the contaminants and the fibers decreased. Still, it is interesting to find that the decrease in the NPM after dyeing showed a good liner relationship ($R^2$>0.99) with the concentration of the PSA labels. However, the decreasing trend in the NPM values could not account for the increasing amount of the PSA. Therefore, it was concluded that it is difficult to quantify the PSA in the deinked mixed office paper pulp by the dye method due to the interference of the residual toner inks.

In order to modify the dye method, the NPM of residual ink specks was quantified based on the prediction method employed in the high-low scanning contrast method. That is, the NPM of ink specks was predicted from the NPM of the handsheets before dyeing at the contrast of 20, and the NPM of the PSA specks was equal to the NPM of the dyed handsheets at contrast 55 minus the predicted NPM of ink.

The data from the high-low scanning contrast method and the modified dye method are shown in Figure 7. As shown in Fig. 7, the NPM of ink changed slightly (high-low scanning contrast method) through the various concentrations of PSA labels. However, the variation was rather small and showed good reproducibility.

The NPM of "Contrast PSA" is the NPM of PSA obtained from the high-low scan contrast method. The NPM of "Dyeing PSA" is the NPM of the PSA obtained from the NPM values of the dye method, and both were measured at contrast 55. They showed good linear correlations ($R^2$=0.9856 and $R^2$=0.9716) with the concentrations of PSA labels. However, their absolute values were different. Therefore, it is concluded that both

the high-low scanning contrast method and the modified blue dyeing method could be used to measure the PSA and ink contaminants in the deinking system with almost the same accuracy, but that they can only offer a relative value of PSA or residual ink specks.

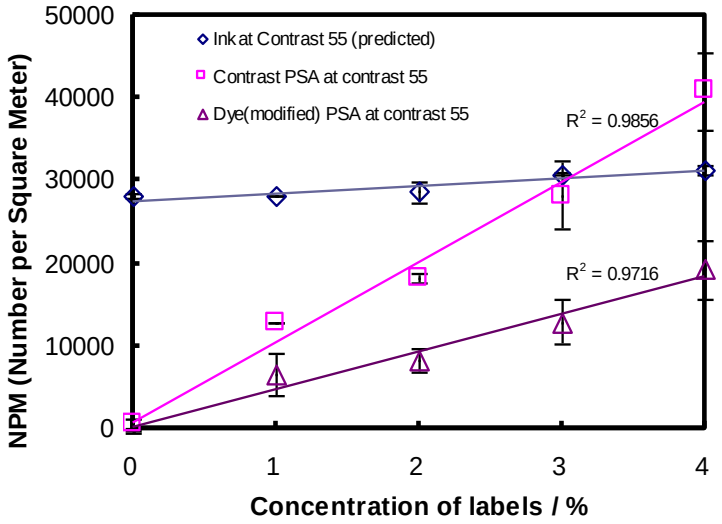



**Fig. 7.** Application of high-low contrast scan method in agglomeration deinking system

## Potential Application of the High-Low Scanning Contrast Method in Laboratory Study of PAS in Deinked Pulp

The high-low scanning contrast method performed quite well in quantifying the PSA with the presence of ink from the HP1010 printer in the laboratory deinking system with and without agglomeration agent. It is hoped that this method would also give a relatively reliable value of PSA with the presence of other types of ink contaminants. Therefore, it is suggested that the high-low scanning contrast method could be used to quantify the PSA for further studies such as their interference to different types of toner inks and/or surfactants in a more complicated deinking system. It is also hoped this method can be further modified to be used in real mill applications.

## CONCLUSIONS

1. Both the hot-pressed residual PSA and toner inks in the office waste deinked pulp handsheets are sensitive to the contrast value in the image analysis technology. The PSA specks cannot be found at low contrast value, and the toner ink specks can be found throughout most of the contrast range. It is very difficult to accurately quantify the PSA value when there is interference from toner inks.
2. The toner ink exhibits a very good linear relationship throughout most of the scanning contrast values. The result at the high contrast value can be accurately predicted from its value at a low contrast value.
3. The difference between the actual NPM result (PSA plus toner inks) at high contrast value and the projected NPM result of the toner inks from the low contrast value, which is called "the high-low scanning contrast method", can give a relatively

reliable NPM value for the residual PSA with minimal interference from the residual toner ink.

4. The high-low scanning contrast method could be a potentially effective laboratory tool for quantifying the relative concentration of residual PSA for future studying of its interference with different types of toner inks and/or surfactants in a more complex deinking system.

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