Understanding Post Finishing Performance of Xerographic Prints

Guiqin Song, Gordon Sisler, Suxia Yang, Kurt Halfyard, Ed Zwartz; Xerox Research Centre of Canada; 2660 Speakman Drive, Mississauga, Ontario, Canada, L5K 2L1

Abstract

Xerographic digital presses have been used for the production of a variety of publications. Some of these applications may employ hot melt adhesives or pressure sensitive adhesives. However, good adhesion can be hard to achieve with xerographic prints due to the presence of residual fuser release agents on the surface of prints. Also this adhesion problem is very complex since the release agent and paper coating chemistries, fusing process, post-finishing materials and processes are all involved. Thus, it is important to understand the chemistry of release reagent and the surface topography and chemistry of substrates as well as the interaction between them. A method to predict the general adhesion properties of the xerographic prints and their behavior towards finishing operations was developed. It was found that the residual oil on the surface of the prints affects the finishing performance. When the surface coverage of oil is above a certain threshold, post finishing problems appear. The surface coverage of oil depends not only on the oil rate per copy but also on the molecular structure of the oil as well as the substrates.

1: Introduction

Many outputs of the xerographic digital presses have been involved in the post-finishing and bindery operations as well as other potential post-press processes. Some binding processes use hot melt adhesives or pressure sensitive adhesives. However, the post-finishing performance can be affected by Polydimethylsiloxane (PDMS) oil which was introduced to help toner release during the xerographic printing process. Thus the xerographic prints generally contain some level of residual PDMS oil and this can cause the reduction of the adhesion and de-lamination of bonded articles.

The most common types of oil used for releasing toners are silicone oil modified with some functional groups such as amino group or mercapto group. For amino silicone, there are many studies in the field of fabric and related materials as it exhibits superior softening benefit and mechanical properties [1, 2]. T.J. Kang et al. have proposed that a film of amino silicone forming on the cellulose lowers the friction coefficient of the cellulose surface [3]. Y.J Xu et al. synthesized a series of amino silicones with different amino values and studied their morphology, hydrophobic properties and surface composition of the silicon layers on cotton fibers and cellulose substrates [4]. They found that the roughness becomes smaller with an increase in the amino value. Their study along with earlier work done by An et al. [5] and Burrell et al. [6] suggests that the orientation of amino silicone molecules is with the amino function groups adsorbed onto the cellulose interface while the main polymer chains and the hyrophobic Si-CH_3 groups extend toward the air. Another type of commonly used silicon oil for toner release is mercapto silicone oil.

Another important player affecting post finishing is the paper substrate. It is well known in paper industry that different manufacturing process can affect paper wetting ability and penetration by liquids such as oil or water [7]. At one extreme are tissue papers and toweling, which are designed to absorb water quickly. At the other extreme are cupstock and greaseproof papers which are designed to inhibit the passage of liquids. It is not unexpected that binding property may be affected by the type of the paper that we use other than the silicone oil.

The last player affecting the binding performance is the adhesive. Due to the length of the paper, we chose one commercially available hot melt adhesive and set it as a constant in order to study other two factors - oil and substrate. The discussion of the adhesives will be summarized in a separate paper.

In this paper, we tackled the end user adhesion problem by studying the modified PDMS oil and substrate as well as the interaction between them. The effect of different functional groups (amino vs mercapto), the loading level and the location of amino functional group on binding is studied. The interaction between the oil and two different paper substrates is also studied.

2: Experiment

2.1: Paper Sample Preparation

Prints with different oil rates were generated on purpose in order to investigate the oil rate effect on post finishing process. Two one side coated paper A and B were used for this study. Paper A is a conventionally coated paper and paper B is a cast coated paper. The prints were oiled with the uncoated side in contact with the fuser roll which transfers a thin layer of silicone oil onto the paper surface.

2.2: Bulk Oil per Copy Measurement

PDMS oil rate on paper was measured using Inductively Coupled Plasma Emission Spectrometer (ICP-OES) ICAP6000 series. In detail, the instrument was first calibrated using a prepared silicone oil standard (a mixture of silicone oil and kerosene). The silicone oil in the paper was extracted into kerosene and measured with the calibrated instrument to determine the oil in terms of milligram of per copy.

2.3: X-ray Photoelectron Spectroscopy Measurement (XPS)

XPS is a surface analysis technique that provides elemental, chemical state and quantitative analyses for the top 2 – 5 nanometers of a sample's surface. A region about 1 millimeter in diameter was analyzed. Three sections were cut from each print, upper left, center and lower right. Three areas were analyzed to determine the uniformity of distribution of the residual fuser oil. Silicone concentration was reported in units of atomic percent and then was converted to the percentage of area coverage by PDMS oil. We found that the difference among these three locations is small and the average percentage of area coverage by PDMS oil is used in the following discussion.

2.4: The Binding/Adhesion Test

An in-house binding/adhesion tester was developed and sandwich samples (paper/adhesive/paper) were prepared using the paper samples mentioned earlier. A commercially available hot melt adhesive US661 from "Coating and Adhesive Inc." was used for this experiment. The sandwich sample was then peeled by hand and visually inspected for the percentage of fiber tear (0%~100%). 0% means separation at the interface between these two paper (adhesive layer) and 100% means separation within one of the paper substrates (not the adhesive layer). The higher the fiber tear, the better the adhesion.

3: Results and Discussion

Figure 1 shows the surface oil rate measured by XPS in terms of silicone surface area coverage as a function of bulk oil rate measured by ICP for the pendent amino oil with low loading level of amine on paper A, which is a conventionally one-side coated paper. It can be seen that in the low bulk oil rate, the surface oil increases with the bulk oil rate but then it becomes a constant around 45% independent of further increase in bulk oil. This observation can be explained using equation (1).

$$\text{Bulk oil} = \text{surface oil} + \text{internal oil} \qquad (1)$$

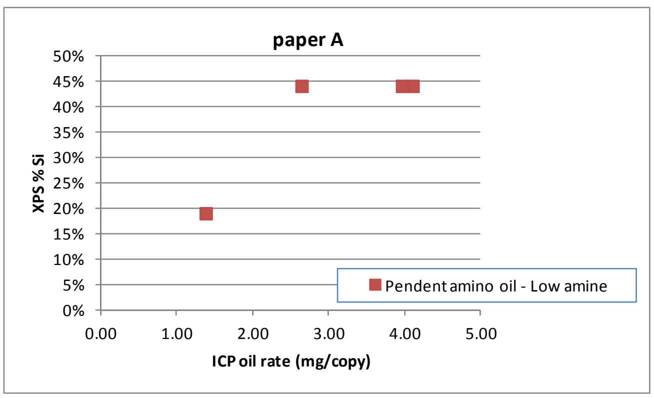

Figure 1, Surface oil measured by XPS as a function of bulk oil rate measured by ICP for a pendent amino oil with low loading of amine on paper A.

The ICP bulk oil contains both surface oil and internal oil. The oil penetrates into the paper substrate through the surface. When the amount of oil applied is very low, almost all the oil with functionalized groups bonds together with the surface fibers while non-functionalized oil can always penetrate into the paper and it's not measured as surface oil. Thus the surface oil will increase as more oil is applied - the increase in the bulk oil. As we further increase the amount of oil applied, the surface fibers will become saturated, but there will still be more oil penetrates into the paper as internal oil. Thus bulk oil will continue to increase but surface oil will stay constant.

Figure 2 shows the surface oil rate as a function of bulk oil rate for three different types of amino oil - a pendent amino oil with a low loading level of amine, a pendent amino oil with a high loading level of amine and a end unit amino oil on paper A. It can be seen that the surface oil for all three types of oil saturates but at different values. Higher the amine loading level is, higher the saturated surface oil coverage. At the same bulk oil rate, e.g. 4.0mg/copy, the surface coverage of oil for the end unit amino oil is only around 20%, while the pendent amino oil with high amine loading is around 65%. This suggests that end unit amino oil penetrates easier than the pendant amino oil. This confirms Y. Xu et al.'s [4] proposed model that the amino groups are fixated with the –OH group of the cellulose surface. The higher the amino value, the more bonds between amino group and –OH group, thus the stronger the bond and harder to penetrate into the paper substrate.

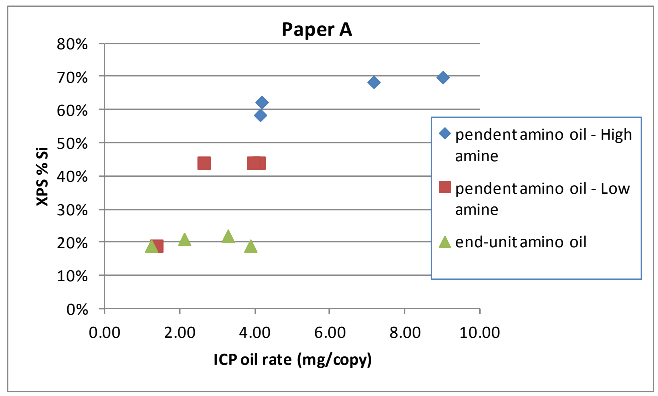

Figure 2, Surface oil coverage measured by XPS as a function of bulk oil rate measured by ICP for three different types of amino silicone oil.

Figure 3 gives the surface oil as a function of bulk oil for the same pendent amino oil with high amine loading level as discussed previously and a pendent mercapto oil on paper A and paper B as shown in figure 4. Paper A and B have similar thickness. Paper A is conventionally one side coated paper and Paper B is a one side cast coated paper. For both types of oil, paper A gives higher surface oil than paper B. This can be explained from the differences in surface morphology and treatment of these two papers. Figure 4 gives the SEM of a blank paper A and a blank paper B, together with their corresponding oiled prints. Here the oil is the same pendent amino oil with high amine loading as we discussed earlier. It can be seen that paper A has a porous surface with fibers clearly seen on the surface, while paper B has no visible fiber on the surface. As the functionalized oil prefers to attach to the –OH of the fiber, paper A will most likely to contain higher surface oil. For paper B, it is the opposite and most oil penetrates inside and the residual oil seems to interact with the

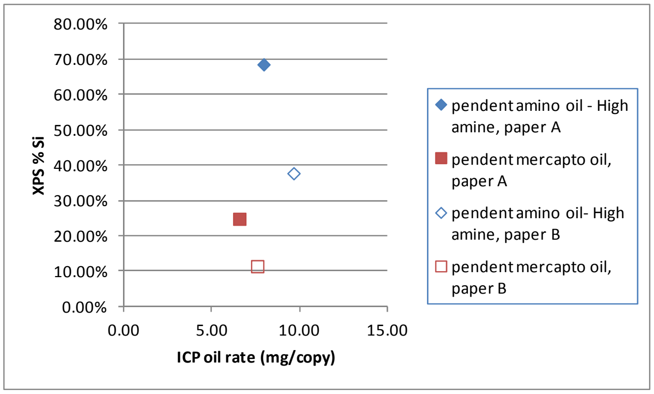

***Figure 3**, Surface oil vs bulk oil for two different types of oil on two different paper substrates.*

paper additives to form isolated islands. Figure 3 also shows that for the same paper substrate, the pendent amino oil has higher surface oil than the pendent mercapto oil. This suggests that amino functional group has higher reactivity with –OH group than the mercapto functional group.

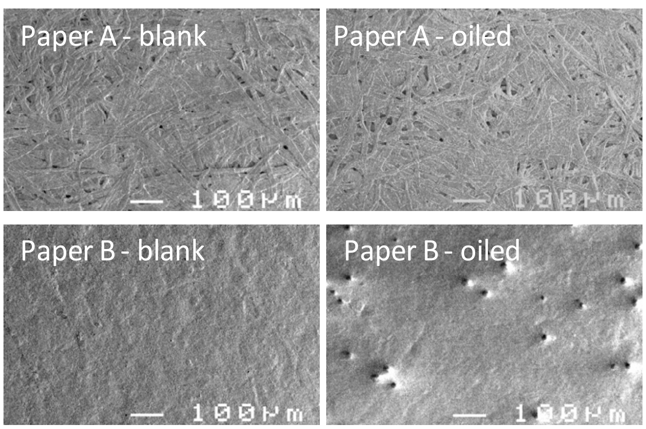

***Figure 4**, SEM of blank paper A and B (left) and their corresponding oiled images.*

Binding process is the bonding between two separate sheets of paper through interaction of adhesives. It is expected that as the surface of the prints become more saturated with silicone oil, the surface will be more hydrophobic and the surface free energy is low. This will cause the de-lamination of the bonded articles. Fuser oil is much easier to penetrate into the paper and hiding beneath the surface for paper surface covered with clay (Paper B). However, the surface covered with fiber is rich with –OH group. It is much easier to react with the functional group in PDMS oil especially amino group. This will result in the PDMS oil attached on and covering the surface of the prints (Paper A). Thus it will cause adhesion failure – de-lamination of papers. For our binding/adhesion test, we measure the percentage of fiber tear. Figure 5 gives the fiber tear results for the three sets of oil discussed in figure 2, the pendent amino oil with high loading level of amine has the highest surface oil coverage and the lowest fiber tear. The end unit amino oil has the lowest surface oil coverage and the highest fiber tear.

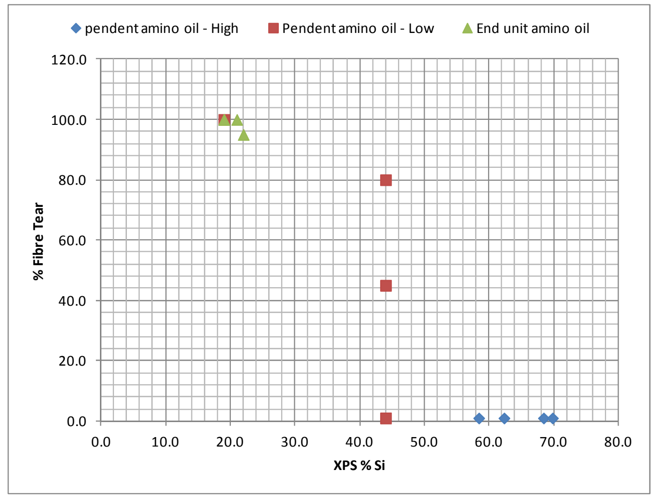

***Figure 5**, Fiber tear as a function of surface oil measured by XPS.*

When the coverage of oil is above the threshold around 45%, post finishing problem appears. This indeed confirms our prediction that high surface oil coverage lowers the surface free energy and causes bonding issue.

Summary

In summary, we tackled the end user adhesion problem by studying the PDMS oil and substrate as well as the interaction between them. We found that amino functional group bonds more strongly with the fiber than mercapto functional group, resulting in more residual surface oil. Also the higher amine loading level, the more surface residual oil. Papers with more fiber exposed on the surface tend to retain more surface oil than papers with fibers covered up. It is the residual surface oil that affects the post finishing adhesion application. When the coverage of oil is above the threshold around 45%, post finishing problems appear.

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Author Biography

Guiqin Song received her M Sc. in Polymer Engineering Material Science from South China University of Technology in 1987. From 1987 to 1999, she was a research scientist at Non-Ferrous Metal Research Institute in Guangzhou, China. In 2000, she joined the Xerox Research Center of Canada and has worked on various research and development projects such as "Media Latitude Study", "Xerographic Prints Post Finishing Application", "Varnish for Xerographic and SIJ Printing Process" etc.

Suxia Yang received her BS in honor physics from Nanjing University in China (1998) and her PhD in physics from Hong Kong University of Science and Technology (2002). She then worked at the Center for Advanced Nanotechnology on photonic crystals and optical characterization of nano-structures. In 2007, she joined the Xerox Research Center of Canada and has worked on the research and development of various consumables such as fuse materials, toners, additives and carriers for xerographic printing.