Causes of Gloss Ghosting and Effect of Properties of the Paper on the Gloss Ghosting

Hideki Takada^{*2}

Development Sec., Technical Dept., MPM OPERATION Co., Ltd.^{*1}

Yoshihiro Tamura

Administration Dept., Mitsubishi Paper Engineering Co., Ltd.

Hideki Takada

Yoshihiro Tamura

Abstract

Gloss ghosting is an undesirable phenomenon that occurs in the sheet-fed offset printing. An ink gloss differential on the reverse side imagery appears in the form of a ghosted image of the front side printing. As it gives a significant damage to the appearance of the printed product, the value as a commodity deteriorates. It was reported that oxidizing vapors released from the drying ink of the front side printing accelerate the drying of the reverse side ink film between adjacent sheets in the printed load. However, the detailed mechanism of gloss ghosting has many unclear points. We have investigated what is happening on the surface of the printed ink film, and the effect of the paper properties on the gloss ghosting.

In our study, it was confirmed that the condition of contact between the front side printing surface and the reverse side printing surface is important to determine whether the gloss ghosting occurs or not. It was found that the time interval between front side printing and reverse side printing greatly influences the gloss ghosting. We were able to clarify the mechanism of the gloss ghosting by tracking both the oxidizing vapors generation amount from the front side printing and the arithmetic average roughness Ra of the surface of the printed ink film. Gloss ghost appeared clearly as the difference in Ra value between the printed surface accelerated drying by oxidizing vapors and the surrounding area was larger. In conclusion, there was a tendency that gloss ghosting is less likely to occur in printing papers with smaller variations in Ra value over time on the printed surface.

Keywords : Gloss ghost, Sheet-fed offset printing, Ra value on the printed surface

1. Introduction

Digital printing is growing at a steady rate. But offset lithography is still the dominant process for commercial printing of advertisement inserts and catalogues, and

publication printing of books and magazines. Presses are either sheet fed or roll (web) fed. Oxidation polymerization inks were generally used in sheet-fed offset printing. When the printed ink is dried and set, the subsequent procedures are carried out to make the final product. In operating a single-side sheet-fed offset printing, papers are printed on the front side, preserved for the printed ink to dry for some time (usually one day), turned upside down and printed on the reverse side (Fig. 1). Re-

^{*1} Aomoriyachi, Kwaragi, Hachinohe-shi, Aomori 039-1161, Japan

^{*2} E-mail : takada_hideki@mpm.co.jp

Fig. 1 Single-side sheet-fed offset press

Fig. 2 Gloss ghosting

cent trend is that the number of double printing press is increasing.

Gloss ghosting is an undesirable phenomenon that occurs in the sheet-fed offset printing (Fig. 2). The front side printed image is transferred and appears on the reverse side. It looks like a ghost and gives visible gloss mottling pattern. It is speculated that printed image on the reverse side of a paper is affected by the front side image printed on the adjacent paper during the time these two papers are stacked together. As it significantly damages the appearance of the printed product, its esthetic value deteriorates. When gloss ghost troubles happen, we must find effective countermeasures and perform the printing job again until the qualities specified by customers are obtained. One of the countermeasures is that comparing the area of two images on the front and reverse sides, we print the larger side first and wait for the printed ink to dry before we print the smaller side. It is reported in a literature¹⁾ that oxidizing vapor that is released from the drying ink in the oxidation reaction migrates to the adjacent sheet and accelerates drying of the ink printed on the reverse side. Another report²⁾ estimated that the varnish in the printed ink

penetrates through the paper structure from the front side to the reverse side and affects the printed image. But the detailed mechanism of these two hypotheses has not yet been elucidated. It is confusing to see that gloss ghosts sometimes look glossy and other times look like matt-finished. We will study the causes and effects of paper characteristics on gloss ghost.

2. Experimental

2.1 Printing on papers

Printing tests were carried out by using a laboratory RI printability tester I type (AKIRA) with commercially available sheet-fed offset printing N type ink. Commercial matt-finished art papers of basis weight of 127.9 g/m² were used for experiments described in the following 3.1–3.3 sections and all that follows 3.4 experiments employed six paper grades from commercial coated art papers. As a preliminary survey, good correlation was confirmed on the occurrence of gloss ghost between a RI printing tester and a real sheet-fed offset printer.

2.2 Analysis of vapor components released from printed paper

Volatile components from printed papers were collect-

ed at 25°C with a collection tube (GERSTEL : TEL), heated to desorb components with a heating and desorbing apparatus (GERSTEL : TDU-CIS4) and introduced into GC-MS (Ajilent : 7890A-GC, 5975C-MS) equipped with a column (INNOWAX : 60 m-0.35 μ m) to characterize vapor components by MS spectrums. The heating temperature profile was controlled at 40°C (5 min.)–240°C (15 min.), 10°C/15 min.

2.3 Non-contact measurement of surface roughness of solid print

According to Japan Industrial Standard (JIS B0601 : 2001), surface roughness of printing face was measured with the non-contact method using a laser microscope (KYENCE Japan: VK-8700) and arithmetic average, Ra of surface roughness measurements was calculated.

2.4 Spectral colorimetric measurement of solid print

Intensity of gloss ghost was quantified by spectral colorimetric measurement of solid print area using a spectral colorimeter (KONICA MINOLTA: CM-3600A). Both SCI (Specular Component Include) and SCE (Specular Component Exclude) methods were employed.

3. Results and Discussion

3.1 Basic experiment on gloss ghost I

We performed experiments described in Fig. 3. In the preprint, we made solid printing on two coated papers of the same grade by using a laboratory RI printability tester. After the surface of the ink was dried, two printed papers were stacked together by facing the printed side right up : the reverse side of a paper was made in contact with the front side of the adjacent paper. Sinkers were placed on the top of the paper stack to apply the pressure of 1.3 g/cm² for 24 hours. The top and bottom papers of the pile were designated as A and B respectively in this experiment. Next day the succeeding solid printing was performed on the reverse sides of each pa-

per. The area of solid print in the succeeding print was designed larger than that in the preprint. Two papers were left separately without making them contact each other for another 24 hours.

As was mentioned, during the first 24 hours, the reverse side of A was in touch with the front side of B. If the hypothesis is true that oxidizing vapors which are released from the preprint ink drying by the oxidation reaction migrate and accelerate the ink drying of the adjacent paper, gloss ghost could happen at any time on the reverse side of A in the succeeding print. If another hypothesis is correct that solvent in the preprint ink penetrates through the paper structure from the front side to the reverse side and affects the printed image on the reverse side, it wouldn't be surprised if gloss ghost occurred on the reverse side of B in the succeeding print. But gloss ghost was not observed in either case at all.

3.2 Basic experiment on gloss ghost II

Fig. 4 describes the experimental procedures. We prepared two printing papers of the same grade that we had used in the 3.1 experiment. In the preprint, small-size solid print was made on the front side of A. Twenty four hours later, large-size solid print was made on the reverse side of B in the succeeding print. When the ink was set to some extent in 5 minutes, the front side of A was made contact with the reverse side of B and the paper stack was kept for 24 hours. As a result, gloss ghost was observed on the reverse side of B.

In commercial double-side printing, printed papers are piled up. In the 3.1 experiment, two printed papers were stacked together one after another after the preprint for 24 hours, preserved separately without touching each other after the succeeding print for another 24 hours. No gloss ghost was observed. In the 3.2 basic experiment II, two papers were kept separately for a day after the pre-

Fig. 3 Basic Experiment on Gloss ghosting I

Fig. 4 Basic Experiment on Gloss ghosting II

print. Following the succeeding print on the reverse side, two papers came in contact with each other under the pressure for a day. As a result, gloss ghosting happened. These two experiments indicate that effects of stacking papers after the single-side printing is small on gloss ghost occurrence in contrast to the large effects of stacking papers after the double-side printing. To confirm these phenomena, the following experiment was performed.

The experimental procedure was similar to the 3.2 experiment except the stacking position after the succeeding print : it was slightly shifted. Top and bottom papers were designated as C and D respectively. In the preprint, small solid print was printed on the front side of both papers, stacked, and left for 24 hours. In the succeeding print, large solid print was printed on the reverse side of C. Five minutes after the ink was set to some extent, the front side of D was made contact with the reverse side of C at a slightly shifted position. Pressure was applied and the paper stack was left for another 24 hours. I was found that loss ghost was observed not on the precisely opposite location of preprint image but on the slightly shifted location where two solid print images overlapped each other.

3.3 Effects of set time of preprint ink on gloss ghost

We studied the effects of set time of the preprint ink on the intensity of gloss ghosts by performing the similar experiments described in Fig. 4. The setting time was changed from 4 hours, 24 hours and 48 hours. Gloss ghost rankings were evaluated with respect to visual examination as follows :

(visible) 24 hours > 48 hours > 4 hours (invisible)

In addition, we analyzed vapors released from the preprint ink two days after the solid print was made on papers by RI printing tester in order to elucidate what is happening in the preprint. As a result, saturated aliphatic aldehydes, unsaturated aliphatic aldehydes and alkyl furans were detected. Especially the largest emission was identified as n-hexanal and n-pentanal. The second largest emission included 2-ethyl furan, 2-butyl furan and 2-pentyl furan. Generation of n-hexanal had been pointed out in the literature¹⁾ too. The amount of these five vapor compounds was quantitatively analyzed by the peak area of GC-MS intermittently after preprint. As shown in Fig. 5, they became maximized at 24 hours and gradually declined. This time-dependent changes of vapor emission were found to be correlated well with the changes of gloss ghost intensity.

The reference¹⁾ noted, "Aldehydes that are emitted from preprint ink accelerate drying rate of the inks in succeeding printing." In order to confirm whether this theory could be applied in our study or not, we retested the experiments described in the reference¹⁾ by using sheet-fed offset printing ink. Onto the surface of two prepared glass slides for microscope, commercial sheet-fed offset printing ink N-type was transferred from a printing roll. A small amount of n-hexanal (WAKO CHEMICAL : first class chemical) was dropped on the surface of another slide, which was placed at the bottom of a glass container. A lid of the container was tightly shielded to prevent leakage of the vapor. The slide on which ink film was transferred was placed at the upper part the container, 3 mm distant from the bottom slide on which n-hexanal was dropped. Two slides were

Fig. 5 Change with time of oxidizing vapors amount released from the printed ink film

Fig. 6 Acceleration the drying of ink film in situ with hexanal vapors

placed separately without touching each other. As shown in Fig. 6, the ink film was exposed to n-hexanal vapor emitted from the bottom slide. These two slides in a container were preserved at the normal temperature for six hours. As a control, a pair of slides was preserved without use of n-hexanal. When we wiped out the ink from the surface of slides with gauze, we found that the dryness of the ink film that was exposed to n-hexanal vapor was higher than that of the ink film that was not exposed to it. It was found that the experimental results in the reference¹⁾ were duplicated.

If that is the case, a question occurs to my mind. Generally in offset printing, when the drying rate is high, the setting time is not long enough to level unevenness of ink film surface created by the cleavage of the ink layer at the nip between an offset roll and a paper web. It

would give low gloss. However if the vapor is assumed to promote drying of the ink, gloss ghost would have higher gloss than the peripheral area and look glossy-finished. In some cases, gloss ghost had lower gloss than the surrounding non-ghost area and looked like matt-finished. Therefore further experiments were performed to understand these phenomena.

3.4 Mechanism of glossy-type and matt-type gloss ghost

3.4.1 Fundamental research on the tendency of gloss ghost occurrence

We collected printed samples that contained gloss ghosts. They were printed by commercial sheet-fed offset printers. Some gloss ghosts looked matt-type while others looked glossy type. The difference were distinguished by visual examination. In order to achieve nu-

merical evaluation, ink density was measured with a gloss meter, using 60-degree incident light. But the difference between the matt-type and glossy type were not quantified. Next a non-contact laser microscope which could pinpoint a small spot was employed to measure surface roughness of gloss ghost and its surrounding non-ghost area. Ra is the arithmetic average of surface roughness. It was found that Ra of glossy-type ghosts was smaller than that of peripheral area. In the case of matt-type ghosts, the opposite data was obtained: Ra of gloss ghosts was larger than that of the surrounding area.

Six commercial coated art papers (samples ①~⑥) were solid printed with a laboratory RI printability tester and time-dependent changes of surface roughness of printing face were measured by the non-contact method using a laser microscope. Samples were fixed at the same position of the laser microscope stage to measure the same position of papers. Each sample (①~⑥) was preprinted on the front side, preserved for 24 hours and printed on the reverse side in the succeeding print. Five minutes later, printed papers were stacked one after another so as to contact the front side of a paper with the backside of another paper for 48 hours. Intensity of gloss ghosts was ranked by visual examination. It was found that gloss ghosts were not observed in sample ① and ②, visible in sample ③ and conspicuously visible in sample ⑤ and ⑥. Fig. 7 shows the time-dependent changes of Ra of samples ①~⑥. It was found that printed samples with large Ra gave conspicuous gloss ghosts in contrast to those with small Ra that did not give gloss ghosts.

Fig. 7 Change with time of the arithmetic average roughness Ra of the surface of the printed ink film on the paper sample ①~⑥ (Variation range of Ra value with time)

3.4.2 Conspicuous gloss ghosts and slightly visible gloss ghosts in single-side printing

Sample ⑤ that had conspicuous glossy ghosts and sample ② that had not visible gloss ghosts were selected from six samples for further experiments. In the case of sample ⑤ as shown in Fig. 8, Ra value of glossy ghost (□ plot) at 48 hours was smaller than that of the surrounding area (■ plot). At the initial stage, Ra of the succeeding print was almost the same whether papers were contacted or non-contacted in the preprint. As was confirmed in Fig. 7, Ra of the non-contact area increased until it reached the peak value and then gradually declined. On the other hand, succeeding print that had been contacted with preprint was affected by vapors released from preprint and the drying rate of succeeding print ink was promoted. As the amount of vapor emission was maximized at 24 hours, there was not enough time for Ra to make an increment and the succeeding print ink was not dried further. The printing face was set during the period of time when the Ra value was low. As a consequence, Ra of gloss ghost in the location that had been in contact with the preprint image was lower than that of the surrounding area. Hence glossy ghost occurred. Concerning the sample ② in Fig. 9, Ra of the contact area at 48 hours (○ plot) was almost the same with that of the peripheral area (● plot). Variation of Ra of was so small that the gloss ghost was not observed.

3.4.3 Matt-type gloss ghost from double side printing

Double-side printing was simulated by using sample ⑤. The succeeding print was performed 5 minutes after

Fig. 8 Change with time of Ra of sample ⑤ (Suppose single-side printing press. Interval between front and reverse side printing is 24 hr.)

Gloss ghosting; Not observed

Fig. 9 Change with time of Ra of sample ② (Suppose single-side printing press. Interval between front and reverse side printing is 24 hr.)

Gloss ghosting; Appeared cleary (Matt)

Fig. 10 Change with time of Ra of sample ⑤ (Suppose double-side printing press. Interval between front and reverse side printing is 5 min.)

Fig. 11 Verification experiment of gloss ghosting mechanism

the preprint. The preprint and succeeding print sides were contacted each other and stacked for 48 hours. The matt-type gloss ghosts appeared. As is shown in Fig. 10, Ra of gloss ghost ($\triangle$ plot) was higher than that of the peripheral area ($\square$ plot) at 48 hours. As was aforementioned in Fig. 5, the amount of gas relief was so little that ink drying rate was not promoted even if the preprint and succeeding prints were overlapped. Therefore Ra of gloss ghost changed over time at the same rate with the surrounding area. When Ra reached the peak, the ink drying rate in contact area began to be affected by the vapor generated from the preprint ink. The printing face that was set at the high value of Ra continued to change

over time. Consequently matt-type gloss ghosts that had higher Ra value than the surrounding area were observed.

3.5 Additional validation

For the purpose of validating the technical information we obtained, we carried out another experiment using sample ② that had small variation of Ra in printed surface and sample ⑤ that had large variation of Ra. Fig. 11 shows the experimental matrix for preprint and succeeding print. In commercial double-printing, we do not use the different papers for the preprint and the succeeding print. This is a model experiment for the sake of validation. It was found that the occurrence of gloss ghost did

Table 1 Measurement with the spectrophotometer on the surface of printed ink film

glossy type ghost	ghost areas			around the ghost areas			ΔE^*
	L*	a*	b*	L*	a*	b*	
SCI mode	27.53	5.02	3.86	27.87	4.79	4.22	0.5
SCE mode	9.73	6.32	0.67	12.32	5.58	1.32	2.8

matt type ghost	ghost areas			around the ghost areas			ΔE^*
	L*	a*	b*	L*	a*	b*	
SCI mode	28.38	0.92	2.15	27.89	0.60	1.77	0.7
SCE mode	20.39	0.81	1.35	17.19	0.53	0.65	3.3

not depend on the preprint but was affected by the time-dependent fluctuation of surface roughness of the succeeding print image : when Ra was large, gloss ghost happened. This provided essentially the same result in the previous sections of our study.

3.6 Characterization of gloss ghost intensity

We reported gloss ghost intensity by subjective ranking as well as non-contact microscopic measurement of surface roughness of printed face. As I previously mentioned, gloss ghost and its surrounding non-ghost area could be clearly distinguished by visual observation. But they could not be numerically characterized either by an ink density meter or a gloss meter using 60 degrees incident light. Intensity of gloss ghost was successfully quantified by SCI (Specular Component Include) method employing spectral colorimetric instrument (Table 1). SCI spectral colorimetric measurement procedure of printing face was as follows : L* of glossy ghost and its surrounding area was found to be 27.53 and 27.87 respectively, which were regarded almost the same value. In the meantime, SCE (Specular Component Exclude) method quantitatively evaluated the difference : L* of glossy ghost and surrounding area was 9.73 and 12.32 respectively. L* of gloss ghost was lower than that of surrounding area, which meant that the amount of diffused reflected light from gloss ghost was less than that of the peripheral area. It did not contradict with the visual characterization that gloss ghost was of glossy-type because the amount of specular reflection light was high. Likewise the matt-type gloss ghost was digitized with SCE method : L* of gloss ghost was higher than that of surrounding area. Color difference ΔE^* measured by SCE method was found to be larger than that of SCI method.

SCE method is valid for both glossy-type and matt-type and relevant in objectively evaluating the intensity of gloss ghosts.

4. Conclusion

In our study, it was confirmed that the condition of contact between the front side printing surface and the reverse side printing surface is important to determine whether the gloss ghosting occurs or not. It was found that the time interval between front side printing and reverse side printing greatly influences the gloss ghosting. We were able to clarify the mechanism of the gloss ghosting by tracking both the oxidizing vapors generation amount from the front side printing and the arithmetic average roughness Ra of the surface of the printed ink film. Gloss ghost appeared clearly as the difference in Ra value between the printed surface accelerated drying by oxidizing vapors and the surrounding area was larger. In conclusion, there was a tendency that gloss ghosting is less likely to occur in printing papers with smaller variations in Ra value over time on the printed surface. Among various commercial coated art paper samples we tested, A2 matt finished coated paper was the most excellent in terms of gloss ghost. In addition we established a reliable test method : SCE spectral colorimetric method is effective in numerically characterizing gloss ghost intensity.

References

- 1) Uwe B., Gina S. : Fogra Research Report. No.50.035K 2, 421-428 (2008)
- 2) TYKK web site. http://www.tykk.com/tykk/to_q_and_a.html