Studies of Ink Trapping IV- Formations of Hollow Hole in the Trapping

Tatsuhiro Murakami, Shu Otsubo, and Ikuo Naito
Dept. Photography, Kyushu Sangyo Univ.,
Matsugadai 2-3-1, Higashi-ku, Fukuoka 813-8503 Japan
(e-mail naitou@ip.kyusan-u.ac.jp)

Abstract

We detected many holes on wet printed surface in ink trapping using polyethylene terephthalare (PET) film with black ink for offset proofing. The holes were divided roughly to two types, **A** and **B**. The former ones were relatively large and these shapes were variable. The latter ones were round and small ($\phi < 10$ μm). The number of the small size holes ($\phi < 20$ μm) increased with decreasing the amount of ink trapped (**y**). The number of middle size ones ($20 < \phi < 50$ μm) has a maximum around **y** $= 2.5$ g m^{-2}. The number of the largest size ones ($\phi > 50$ μm) increased with increasing the **y** value. We obtained similar results in the ink trappings using the PET film with synthetic paper ink. Using the papers, the number of the type **A** holes decreased and the number of the type **B** holes increased according to decrease of air permeability of the paper. Therefore, the type **A** holes are hollow holes yielded by fixed air bubbles between the printing substrate and the ink on a roll, and the type **B** holes must be pinholes yielded by suspended air bubbles in the ink.

1. Introduction

We detected many ink peaks on printed surface immediately after trapping using a cast-coated paper with an offset proofing black ink.[1] We also detected same number of the ink peaks on the inking roll. Therefore, the ink trapping must progress through cavitations theory, because the ink peaks were formed by rapture of ink wall between enlarged air bubbles. The cavities were yielded by air supply from the paper surface. On the other hand, we detected many ink peaks in the ink trapping using polyethylene terephthalate (PET) film, which did not supply air from the surface. By monitoring the printed matter from the reverse side through the PET film, we detected many air bubbles between the PET film and the trapped ink layer.[2] They were formed by ink distribution before the ink trapping. The suspended air bubbles in the ink act as cavities in the trapping.

We also detected many pinholes on the printed surface.[3] Small ones of them are generated slowly according to lapse of time after the trapping. They are caused to air bubbles in the ink. The others are large. Even if we use enough amount of ink, there are many large holes in the solid area. Because we could not detect exfoliations of substrate surface in the trapping, they had to be hollow holes, called to *"SUNUKE"* or *"NUKE"* (Japanese colloquial words). Formations of the hollow hole

are also one of important phenomena to clarify the ink trapping mechanism and control quality of printed matter. We studied the hollow hole formations using PET film with the offset proofing black ink.
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2. Experimental

The 0.10 mm finest PET film in, cast-coated paper and coated paper were used. Three black inks
 (for offset proofing, synthetic paper and web offset) were used. Ink trapping was performed using an Akira Seisakusho Co. Ltd. RI tester RI-4 type at 293 ($\pm$ 1) K. The nip width between inking roller and paper roller was adjusted to 2 mm. After ink distribution of 4 minutes, the ink trappings were carried out. The amount of ink trapped (**y**) was determined gravimetrically. Immediately after the trapping, the wet surface was observed directly with a digital microscope Cheyence VP-6300 type.

3. Results and Discussion
3-1. Direct Detection of Hollow Holes

Immediately after the trapping, we detected many ink peaks, pinholes, and holes on the wet trapping surface. We already reported the formations of the ink peak[1] and the pinhole[3]. Clarifying the ink trapping mechanism, we studied the formations of hole using the PET film with the black offset proofing ink. There are many holes on the printed surface immediately after trapping (Fig. 1). The holes are divided roughly to two types, **A** and **B**.

Characteristics of the type **A** holes are followings; (1) shapes of them are variable, i.e., circle, ellipsoid, triangle, square, dumbbell shape formed by combination of the holes, etc; (2) variable hole size ($\phi = 2 - 120$ μm, average size becomes small according to the decrease of the **y** value); (3) interference stripes around the holes; (4) thin ink film formed behind the hole; (5) un-exfoliation of the substrate surface when we use the papers.

The characteristics of the type **B** holes are followings; (1) small circle shape; (2) vertical U-letter type holes without interference stripe; (3) ink un-adhered dots are at center of bottom; (4) nearly same hole size independent of the **y** value [ϕ on the printing surface = 5 - 10 (web-offset ink), 7 - 15 (offset proofing ink), and 10 - 25 μm (synthetic paper ink)]; and (5) un-exfoliation of the substrate surface when we use the coated papers.
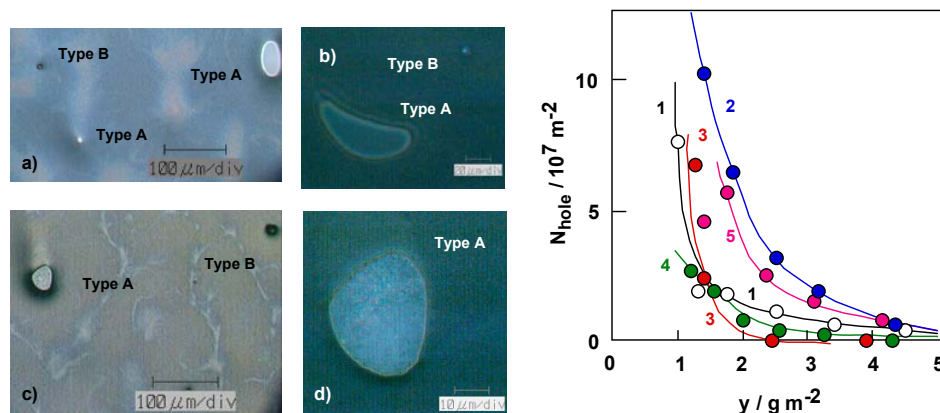
Figure 1. Images of the type A and B holes monitored in the ink trappings using the PET film [**a** (100 μm/div) and **b** (20 μm/div)] and the cast-coated paper [**c** (100 μm/div) and **d** (10 μm/div)] with the offset proofing ink.

Figure 2. Plots of the N_{hole} value *vs.* the **y** value in the ink trappings using the PET film with the offset proofing ink (1), the synthetic paper ink (2), and the web-offset ink (3), and using the cast-coated paper (4) and the coated paper (5) with the offset proofing ink.

3-2. Number of Hollow Holes

We were taking over 25 surface images immediately after trapping using the PET film with the black offset proofing ink, and counted number of the holes (N_{hole}). The N_{hole} value increased with decreasing the **y** value (N_{hole} = 5.5 x 10^7 m^{-2} at **y** = 2 g m^{-2}), as shown in Fig. 2. Initially, we studied the effects of trapping conditions on the N_{hole} value.

The effects of ink distribution time and nip width on the N_{hole} value are small. At constant trapping conditions, we also studied the effects of the printing substrate and the ink variation on the N_{hole} value. In each case, the N_{hole} value increased with decreasing the **y** value (N_{hole} = 7.8 x 10^7 m^{-2} at **y** = 2 g m^{-2}).
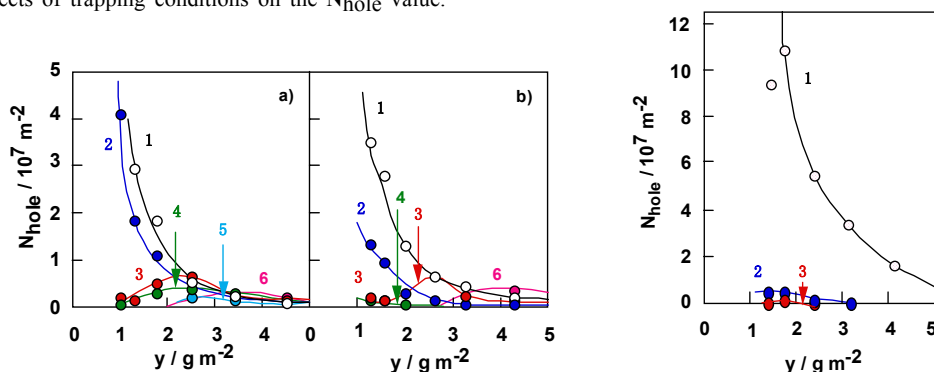
Figure 3. Plots of the N_{hole} value in each size *vs.* the **y** value in the ink trappings using the PET film (a), the cast-coated paper (b), and the coated paper (c) with the offset proofing ink. Size: ϕ < 10 (group 1), 10 < ϕ < 20 (2), 20 < ϕ < 30 (3), 30 < ϕ < 40 (4), 40 < ϕ < 50 (5), ϕ > 50 μm (6).

There were variable shapes of the hole. We calculated diameters (ϕ) of the modified round hole of same area to the actual variable hole. The calculated ϕ values are changeable from small ones (ϕ<10 μm) to large ones (ϕ>120 μm). The almost ϕ values of the type **B** hole are smaller than 10 μm, although the ϕ values at printed surface are larger (ϕ<20 μm). The holes were classified to 6 groups depending on the their sizes, as ϕ <10 (group **1**), 10<ϕ<20 (**2**), 20<ϕ<30 (**3**), 30<ϕ<40 (**4**), 40<ϕ<50 (**5**), and 50 μm<ϕ (**6**). In each printing substrate, the N_{hole} values of groups **1** and **2** increased with decreasing the **y** value (Fig. 3). In the trapping using the PET film with the offset proofing ink, the N_{hole} values of groups **3**, **4**, and **5** have the maximum around **y** = 2.5 g m^{-2}. The N_{hole} value of group **6** increased with increasing the **y** value..

In the ink trapping using the cast-coated paper (air permeability = 28,000 s) with the offset proofing ink, the N_{hole} values of group **1** and **2** increased also with decreasing the **y** value. When we used the coated paper (air permeability =

3,800 s), we measured many small holes (group 1), as shown in Fig. 3c. It is clear that air transmittance of the printing substrate decreases the N_{hole} value of the larger holes.

Because appearances of type **B** hole are completely different from those of type **A** hole, there are different mechanisms to form them. The formations of type **B** hole were studied by means of a relation between its number ($N_{hole B}$) and the **y** value (Fig. 4). When we used PET film, many type **A** holes were formed. The $N_{hole B}$ value in the trapping with the synthetic paper ink is about five times larger than the value in the trapping with the offset proofing ink, although the numbers of the ink peaks on the surface and the air bubbles monitored from the reverse side are twice larger than these values of this sample.[2] On the other hand, in the ink trapping with the web offset ink, we measured many the type **B** holes. In **y** > 2 g m^{-2}, the **y**-$N_{hole B}$ relation agreed with that of the offset proofing ink printed matter. In **y** < 2 g m^{-2}, the $N_{hole B}$ value increased extremely with decreasing the **y** value.

In the ink trapping, printing pressure between the inking roller   and
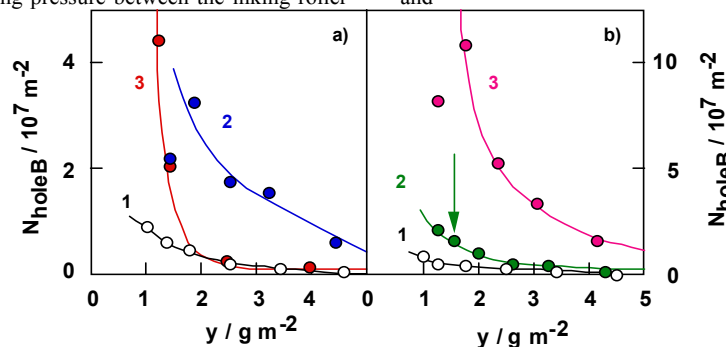
Figure 4. Effects of the ink variation (a) and the printing substrate variation (b) on the relations between the N_{holeB} value and the **y** value.   (a), Using the PET film with offset proofing ink (1), synthetic paper ink (2), and web-offset ink (3); (b) using PET film (1), cast-coated paper (2), and coated paper (3) with the offset proofing ink.

the substrate increases initially and then decreases.   We assumed that the increase of the $N_{hole}B$ value depends on low boiling point solvents of the web-offset ink.

The $N_{hole}B$ value is smallest in the ink trapping using the PET film, an air un-supply substrate.   In the trapping using the paper with the offset proofing ink, the $N_{hole}B$ value of the coated paper (*ca.* 7.2×10^7 m^{-2} at **y** = 2 g m^{-2}) is larger than the value of the cast coated paper (*ca.* 9.5×10^6 at **y** = 2 g m^{-2}). Because the ratio of their air permeabilities (7.4 = 28,000/3,800) is agreed well with the ratio of the N_{hole} values (= *ca.* 8 at **y** = 2 g m^{-2}), the formation of the type **B** hole must be caused by air supply from the paper surface.   In the case of PET film, the suspended air bubbles must yield the type **B** holes.

3-3. Fixing Air Bubbles

During the ink distribution, small air bubbles were suspended in the ink.[2]   The ink peaks and pinholes on the printed surface formed by these small bubbles.   On the other hand, it is difficult to form large holes such as the type **A** holes by the suspended air bubble in the ink.   There are many ink peaks and many hollows on the inking roller before trapping. This uneven ink surface on the inking roller was pressed on the printing substrate.   Air in the hollow must be fixed between ink layer on the roller and the substrate.   Under reduced pressure, the fixed air bubbles become big and then yield the type **A** holes.   Therefore, the type **A** holes must be due to the hollows of the ink surface on the roller.   In our estimation, about one tenth of large hollows on the inking roller yield the hollow holes on the printing surface.

The type **B** holes of the printed PET film seemed to be yielded by the suspended air bubbles in ink.   When we used a paper with low air permeability, the N_{hole} value increased remarkably.   The type **B** holes must be yielded by suspended air bubbles and air supplied through the paper.

References

1) I. Naito et al., Advances in Printing Science and Technology, vol. 31, 113-122 (2006).

2) I. Naito et al., , Preprint of Printing Technology SPb '06, (St Petersburg, Russia) (2006) pp. 53-57.

3) I. Naito and Y. Nitta, Advances in Printing Science and Technology, vol. 32, 59-67 (2006).