Development of Digital Quasi-embossing Technology with an Inkjet Printer-2

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Abstract

Conventional embossing printing technology which can be used to produce metallic glossy images on stereo-shaped objects needs a pressing plate with the image patterns specially arranged. Accordingly, the embossing system is relatively expensive and lacks the adaptability for high-mix low-volume production. Considering these facts, we developed the Digital Quasi-embossing Technology (DQT) which consisted of the technology combined with UV-curable inkjet printing and hot foil-stamping. We reported the DQT for the first time at NIP 28 in Quebec City last year. This paper is a continuation of the last report and describes the following facts. (a) We have improved the adhesion of UV-curable ink to a metallic foil, and consequently we can make not only relatively small-sized products but also large-sized ones with pictures and letters printed thereon. (b) The improved DQT system can produce higher gloss than the last system reported at NIP 28.

Introduction

It is worth making image parts convex in terms of decoration to produce new commercial value for various articles, distinct indication of a particular part such as a carved seal of credit card numbers and supporting device such as Braille. Embossing technology is well known to be used for these purposes. However the conventional embossing method needs pressing plates specially prepared one by one. This fact leads the bad cost performance in particular for the manufacturing of high-mix low-volume products.

We aimed UV-curable inkjet printing methods at the application of the fields described above, because they could provide thick ink layers on various printing media and also produced metallic finish when printing with special inks containing metal particles or scale-like metal fillers. The printing system newly developed by us, which was named Digital Quasi-embossing Technology or DQT, was reported at NIP 28 held in Quebec City, Canada last year. This system worked through digital data control and certainly did not need any pressing plates.

This paper describes the improved system of DQT which enables us to manufacture large-sized, multi-colored and metallic-shining products. Equipment of the improved DQT is the same as that of NIP 28, while some parts of a series of the process have been changed. Samples of the improved DQT will be shown.

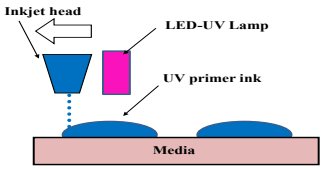
Experimental

We used the following printer and materials.
Inkjet printer: UJF-3042, LED-UV manufactured by Mimaki Engineering CO., LTD.
Aluminum foil transfer film and color transfer film: MURATA KIMPAKU CO., LTD.

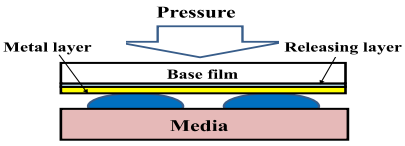
DQT process

The DQT process [1,2] is shown in Fig.1.
(1) As shown in Fig. 1(a), an inkjet printer is used to form a convex-shaped image. Plural layers of UV-curable ink are piled there. The UV-curable ink does not include any colorant. This kind of ink is called primer ink in this paper.
(2) At the second step, a sheet of Al foil transfer film is laminated over the convex-shaped image, and the metal layer of the film adheres to the surface of the printed UV primer ink.
(3) When the base film is peeled away from the laminated Al foil transfer film, the printing of quasi-embossed metallic image is completed.
(4) Coloration can be performed by printing UV-curable colored ink on the top of the quasi-embossing metallic image.

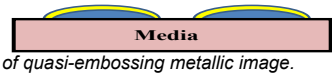
Figure 2 shows a sample made through the DQT process.



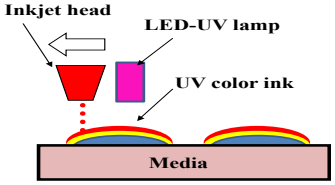
(1) Step for inkjet printing with UV-curable ink.



(2) Step for laminating aluminum foil transfer film.



(3) Completion of quasi-embossing metallic image.



(4) Coloration by printing UV-curable colored ink.

***Figure 1**. DQT process.*

Figure 2. *Print sample by DQT.*

Samples of metallic images made by the last DQT system are shown in Fig. 3. Figures 3(a) and 3(b) are the samples of letter images and a solid pattern image, respectively. Figure 3(b) is an enlarged picture of the part of a circle in Fig. 3(a). The relation between Figs. 3(c) and 3(d) is similar. In this experiment, we used the primer ink of which viscosity was 8.5 mPas at 45 °C and printed ten times for the ink layers to pile up. As seen in these figures, the quality of the metallic images was low. Since the UV primer ink was cured immediately after landing on the printing media by irradiating UV light, there was not enough time to form a smooth surface. Accordingly the motion of the primer ink layer for leveling did not proceed completely and the surface of the piled ink layers became uneven. The depth of the valley in the primer ink layer was about 11 μm as seen in Fig. 3(e). This fact resulted in insufficient transfer of Al foil as seen in Fig. 3(b) and 3(d).

Objective

The last DQT process presented at NIP 28 had the following problems.

(A) Adhesion was not enough between Al foil and UV primer ink.

(B) When colored ink was applied onto the surface of the quasi-embossing metallic image, the gloss of the image notably decreased.

We have tried to solve these problems by adopting some means of improving to the DQT process.

Results and discussion

Improvement of process

We have devised the following two kinds of methods to improve the DQT system.

(A) One is the change in the UV curing process to bring complete leveling of the UV primer ink layers.

(B) The other one is the change in the composition of the UV primer ink.

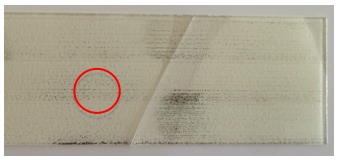
We have tried to improve the DQT system by taking the course of method(A).

As shown in Figs. 4(a) and 4(b), the timing of the UV light irradiation has been changed from the case of the last DQT. The process of ink ejecting is accompanied by UV light irradiation on a usual UV-curable inkjet printer. On the other hand, in this study a UV lamp is turned off during ink ejecting process, and then a UV lamp scans separately. This printing process has brought a smooth surface of the printed ink.

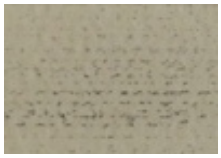
In order to make an ink layer thick, we have tried to repeat the ink printing process ten times and then UV light is irradiated once. In this experiment, however, a smooth surface has not been formed

(a) Sample with poor quality based on bad leveling UV primer ink.

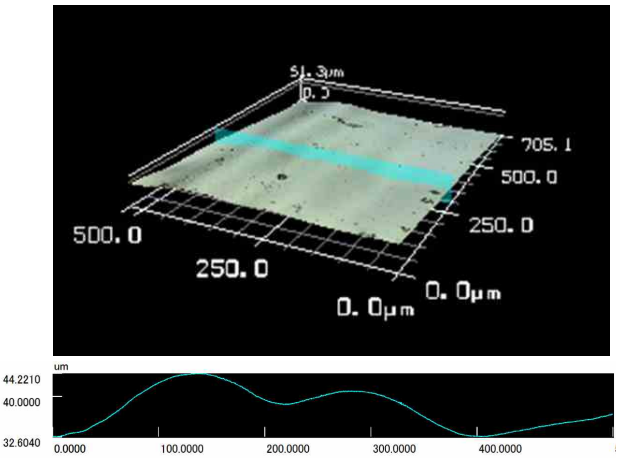
(b) Enlarged photo of circled part of (a).



(c) Sample with solid pattern image based on bad leveling of UV primer ink.

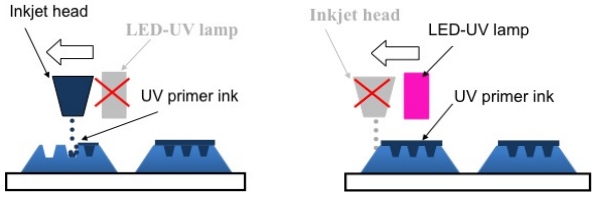


(d) Enlarged photo of circled part of (c).



(e) Surface uneven measurement.

Figure 3. *Example of poor transferred sample by a previous DQT process presented at NIP28.*



(a) Printing is carried out, but not UV irradiation.

(b) UV irradiation is carried out after printing.

Figure 4. *Process of leveling.*

and many wrinkles are observed as shown in Fig. 5(a). Figure 5(b) is a picture of the sample which has been made with 4-time repeated ink printing prior to UV light irradiation, where slight wrinkles are observed.

Figure 6 shows the relationship between ink curing rate and repeating number of ink printing, where we can estimate that only about 40 % ink has been cured in the UV primer ink layer printed repeatedly ten times. We have thought about the melon-like pattern in Fig. 5 that it is caused by the uncured ink oozing gradually through the ink layer itself with making small cracks.

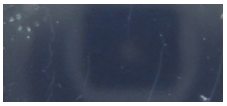
We have examined how many times of repeated printing with no UV light irradiation are needed to bring a smooth surface on the cured ink layer resulted from 6-time repeated printing. Results of transferability in subjective evaluation are shown in Table 1, which indicates that 4-time repeated printing has formed a smooth surface. In this case, the unevenness of the surface has been measured to be 0.4μm. This value may be considered to be sufficient to form a smooth surface. However, we have observed slight wrinkles when the printing is repeated simply four times without UV irradiation. It has also been observed that the ink spreads excessively on the cured ink layer resulted from 6-time repeated printing.

Based on the above facts, we have changed the procedure for 4-time repeated printing as follows:

① Ink printing with no UV irradiation.
↓
② A short time waiting for the ink to do leveling, and then UV light is irradiated.
↓
③ Ink printing with no UV irradiation.
↓
④ A short time waiting for the ink to do leveling, and then UV light is irradiated.

This procedure has improved the degree of leveling as shown in Figs. 7 (b) and 7 (d). Figures 7 (a) and 7(c) are the same as Figs. 3 (b) and 3(c), those are shown again here for comparison among samples.

(a) UV irradiation after 10-time repeated printing.



(b) UV irradiation after 4-time repeated printing on the cured ink layer resulted

Figure.5 *Many wrinkles were formed when printed by 10 or 4 times repeatedly followed by insufficient UV curing.*

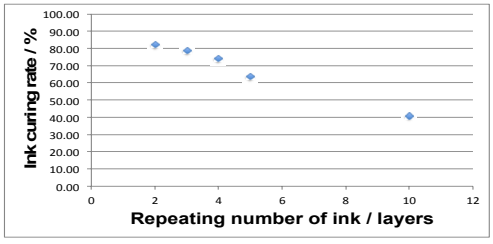
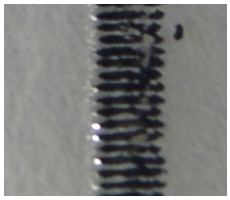


Figure.6 *Relationship between ink curing rate and repeating number of ink printing.*

Table 1 Number of repeated printing.

Number of repeated printing	0	3	4
Difference between top and bottom / mm	11.1	1.2	0.4
Transferability	×	△	○



(a) Enlarged photo of circled part of Fig.2 (a).

(b) Improvement of transcription of (a).

(c) Solid pattern image sample with insufficient leveling.

(d) Solid pattern image sample with enough leveling. Al foil could be transferred well.

Figure.7 Effect of newly devised process in this study on image quality.

DQT process for metallic color

Figure 8(a) is a sample without providing Al foil onto the primer ink. Samples of Figs. 8(b), 8(c) and 8(d) are accompanied with Al foil and made through different process for coloration with a colored UV-curable ink.

When UV light is irradiated immediately after the ejecting of colored ink from a print-head as shown in Fig. 1(d), optical density of the printed image on a surface of Al foil has been low. This fact is thought to be caused by that the ink is solidified too rapidly to spread on a surface of Al foil. The colored ink has been repelled on the surface of Al foil as seen in Fig. 9(a). As a result, the covering of the ink over Al foil is not enough. This results in the low color density and the gloss of the printed surface extremely lower than that of original surface of Al foil. The values of glossiness are shown in Fig. 8(a)-8(d), where they are 17, 25, 165 and 171, respectively.

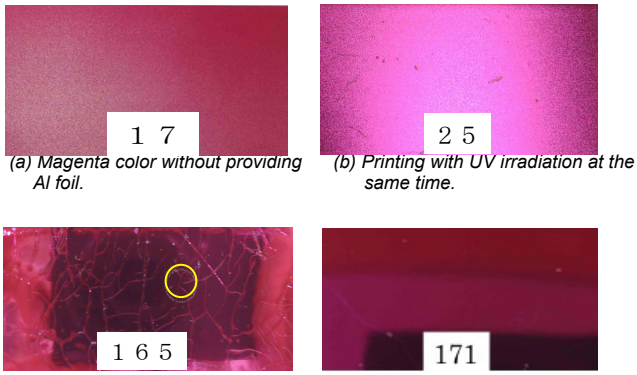
From the above facts, we have considered that the leveling behavior of the colored ink is necessary for high optical density and high gloss. The result in the case that it has taken 60 seconds before UV light irradiation is shown in Fig. 8(c). Although the gloss has been improved dramatically as the glossiness of 165, many wrinkles have appeared in the surface as before. It seems that the ink has been repelled on the Al foil surface as seen in Fig. 9(b)

According to the observation, the ink is not repelled immediately after landing onto the surface of Al foil, but the ink begins to move after a certain period of time. So, we have examined when the ink begins to be repelled. The result is shown in Fig. 10, where the relation between the distance of repelling and a period of time after the ink landing is plotted. We have used Magenta color and radical polymerizable ink. The temperature has

been 21 − 27 °C and its viscosity 23.1 − 17.2 mPas. Under this experimental condition, the period of time has been 19 seconds as seen in Fig. 10. Wrinkle formation has become conspicuous with the time after 19 seconds.

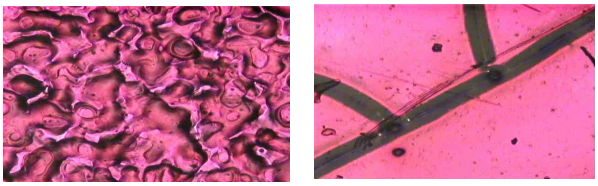
Considering all facts described above, the timing of UV light irradiation has been controlled after the ink ejection from an inkjet print-head. Figure 8(d) shows the result. The surface of the sample is very smooth and there is not a pattern of the wrinkle at all. The glossiness has been 171. While this value is lower than that of original Al foil, we can perceive sufficient gloss and feel a certain aesthetic value.

Figure 11 shows a sample by the DQT system improved in this study, where letter-images have the embossed-shape, multi-colored decoration and metallic gloss.



(a) Magenta color without providing Al foil.
(b) Printing with UV irradiation at the same time.
(c) UV irradiation later.
(d) UV irradiation from external.

Figure 8. *Glossiness of metallic color.*



(a) Enlarged photo of Fig.8 (b).
(b) Enlarged photo of circled part of Fig.8 (c).

Black line parts are based on ink repelling.

Figure 9. *Enlarged photo.*

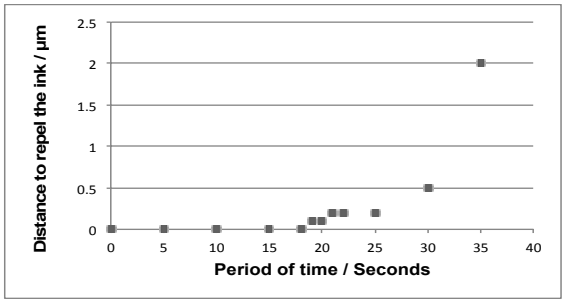


Figure 10*. Relationship between the distance to repel the ink and period of time.*

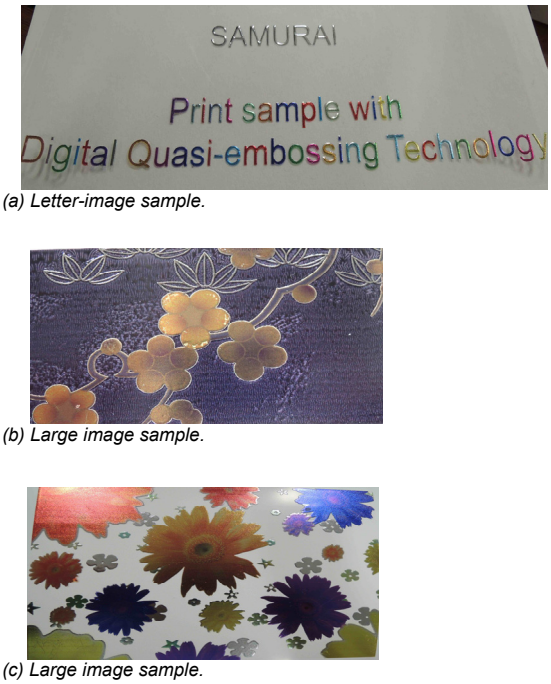
Summary

We proposed the last DQT system at NIP 28, which had some problems to be solved as soon as possible.

We have challenged to improve the DQT system about the problems mentioned below as (A) and (B) in this study. We have been able to succeed in the improvement.

(A) Since adhesion was not enough between aluminum foil and UV primer ink, the quality by the last system was very bad. This problem has been solved by changing the UV curing process to bring complete leveling of the UV primer ink layers. “Leveling” is a key factor for success.

(B) When colored ink was applied onto the surface of the quasi-embossing metallic image, the gloss of the image notably decreased. This problem has been solved by that the timing of UV light irradiation is controlled after the ink ejection from an inkjet print-head.



(a) Letter-image sample.

(b) Large image sample.

(c) Large image sample.

Figure 11. *Metallic color sample by DQT system improved in this study.*

References

[1] Naoki Matsumae, Masaru Ohnishi, Hironori Hashizume and Takao Abe: “Development of Digital Quasi-embossing Technology with an Inkjet Printer”, NIP28, Quebec city, Canada(2012)

[2] Naoki Matsumae, Masaru Ohnishi, Hironori Hashizume and Takao Abe: “Development of Digital Quasi-embossing Technology with an Inkjet Printer”, Imaging Conference JAPAN 2013, Japan(2013)

Author Biography

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