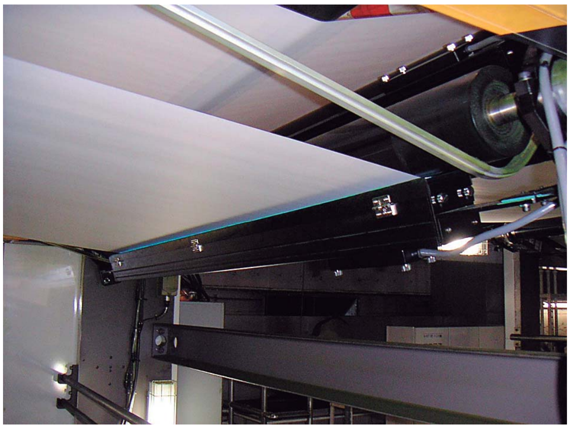

Development of DIAMOND EYE^{TM} the World's First In-line Quality Control System for Newspaper Printing

NORIFUMI TASAKA*1
SHUICHI TAKEMOTO*1
TAKAHIDE TOSHITO*1
SHUNICHI HASHIMOTO*1
IKUO OZAKI*2

The DIAMOND EYE^{TM} in-line quality control system for newspaper printing is the world's first automatic color matching process for color printing, that previously relied upon the experience and skill of the operator. This new technology, which compares target density data based on plate making data, and the results obtained by measuring the density of actual prints acquired by an image sensor on the printer and then controls the density, has made it possible to perform fully automatic, high quality printing from the beginning to the end of printing. This automatic printing capability produces uniform coloring at all times, thus greatly improving printing quality while saving energy and reducing costs such as less wasted paper. Mitsubishi Heavy Industries, Ltd. (MHI) are convinced that DIAMOND EYE^{TM} will become an indispensable digitized tool for rotary presses. Meanwhile, MHI would like to add that DIAMOND EYE^{TM} won the Technical Section Award of the Japan Newspaper Publishers & Editors Association, the Technical Award of The Japanese Society of Printing Science and Technology and the Technical Development Award of The Japan Newspaper Publishers & Editors Association.

1. Background

When a huge quantity of newspapers are being printed simultaneously by many rotary presses in different printing works a great deal of energy and labor are spent doing color matching because of the variations in printing materials and the differences in rotary press characteristics. To solve this problem, the DIAMOND EYE^{TM} quality control system that contributes greatly to the digitalization of rotary presses has been developed. This system has been developed to improve quality, save energy and reduce wasted paper, and it is the world's first practical system that can control the density of rotary presses in a patchless, in-line method.

2. History of development

For a long time MHI have marketed in-line print quality inspection systems and color-tone measuring and contorl systems and based on this have engaged in the research and development of density control technology. However, in order to put density control technology to practical use, it had to be verified with an actual machine under various conditions. Around that time, the Yomiuri Shimbun was beginning to introduce automatic color printing, and a joint project team was launched in 2003. Since then, the project team delivered one Web portion to a Yomiuri Shimbun printing works in November 2004 and one in-line quality control system to another printing works in March 2005, for demonstrative testing. As a result, the Yomiuri Shimbun stated that the system had reached a practically usable level of performance and MHI decided to put it on the market. At present, MHI has begun to sell the system to newspaper companies and has already received many orders.

The advantages of this system are:

(1) Operator adjustment is unnecessary from the beginning to the end of printing because of the pattern density control based on printed image data.

(2) Density control and print quality inspection have been realized by using only one sensor.

This system, which also has plate-position checking and dampening control, is a multi-functional quality control system and has won many awards: the Technical Section Award of the Japan Newspaper Publishers & Editors Association received by the Yomiuri Shimbun, the Technical Award of the Japanese Society of Printing Science and Technology[(3)] received by MHI from The Japanese Society of Printing Science and Technology and the Technical Development Award of The Japan Newspaper Publishers & Editors Association received by MHI from the Japan Newspaper Publishers & Editors Association.

Furthermore, this system has so many technical features that 45 patent applications have already been filed. Described below are the outline, function, results of verification and effects of the system.

*1 Paper & Printing Machinery Division
*2 Hiroshima Research & Development Center, Technical Headquarters

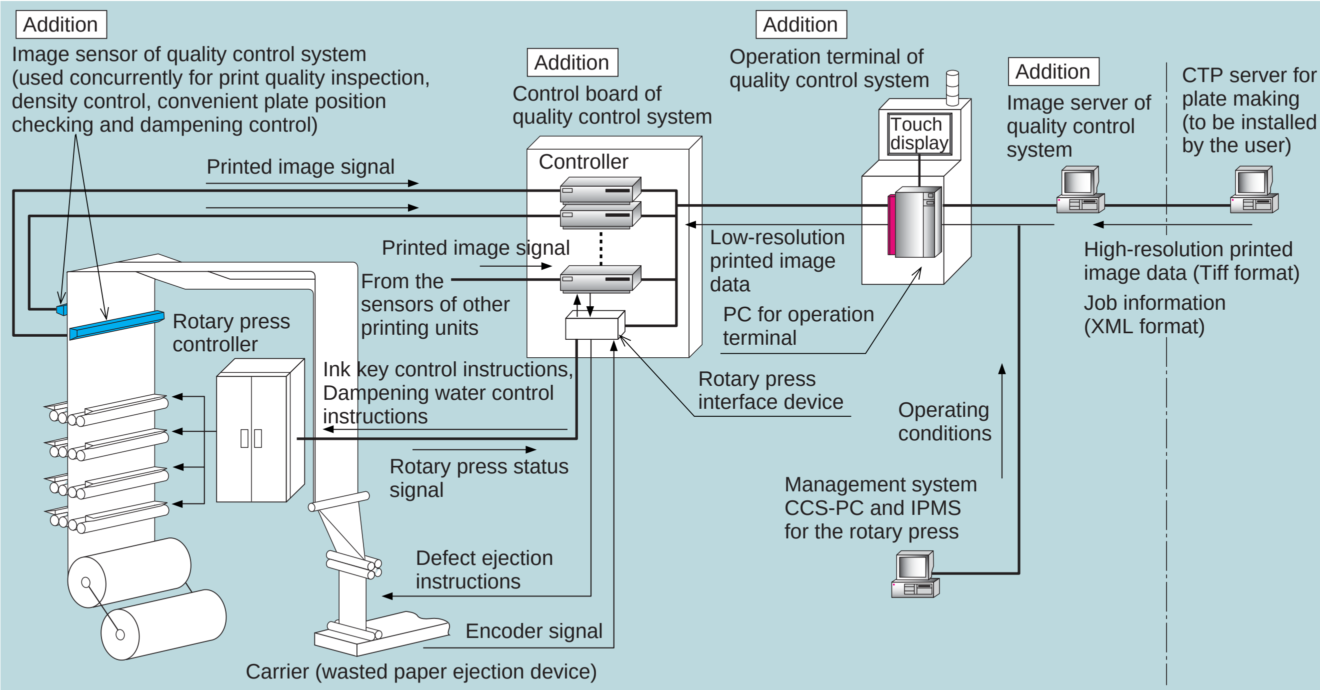

Fig. 1 Block diagram of DIAMOND EYE™ in-line quality control system for newspaper printing

3. Outline of the system[(1)(2)]

Multifunctional capabilities such as density control and print quality inspection have been realized by using only one sensor. This quality control system controls a rotary press by calculating and setting a target value based on the print data acquired from a CTP[(Note 1)] server and the printing characteristics of the rotary press (LUT), and comparing it with an actual printed image acquired from the image sensor on the rotary press (**Fig. 1**).

This system comprises an image server, an operation terminal, a control board and an image sensor. The imager server receives a job information file from the CTP server which contains a high-resolution printed image data file in 1-bit Tiff, print distinguishing information (page, color, etc.) in XML format and a rotary press number. The image server converts the high-resolution Tiff data into control data and accumulates it. The accumulated printed image data is linked with the page allocation data of the rotary press management system, and after being designated a job name from the operation terminal of the system, the printed image data of the designated page is automatically transmitted from the image server to the controller. When printing starts, the controller automatically performs control and inspection based on the printed image data received, and carries our many functions whose details are described below. This system can be installed on both new and existing rotary presses.

Note 1: CTP: Computer To Plate system

4. Function and effect

The density target value is based on the printed image data to start control, thereby requiring no need for operator adjustment from the beginning to the end of printing.

4.1 Density control function

This system makes effective use of printed image data and its density control function meets various user requirements.

(1) Image-based density control

The target density value of each CMYK[(Note 2)] ink color is calculated in units from the printed image data to the ink supplying blade, control begins when printing starts, and the amount of ink supplied is automatically controlled so that the CMYK density of the image read by the sensor reaches the target density. This function is called "image-based density control," which makes it possible for fully automatic control of the whole process from the beginning to the end of printing without requiring an operator.

Note 2: CMYK Cyan, magenta, yellow and black (four process colors for printing)

(2) Good copy control

This function captures the print density after an operator has adjusted the colors as the target density and controls it. This function is called "good copy control." Only the target page is removed from automatic control, and when automatic control of the target page is started again after manual adjustment, this function captures that print density and controls it so as to keep its color tone. This function is for non-process color ink whose frequency in use is small, and is operationally easier than obtaining the color development data each time.

(3) Target density preset

By changing the control target value it is possible to set the density while taking into consideration the final product such as the correction of differences in dry down due to different printing materials.

(4) CMS(Note 3) supporting function

This function reduces the differences in color development characteristics due to different rotary presses and printing materials (called the 1 LUT method(Note 4)) by transferring the printing characteristics, including target density, of a rotary press while is regarded as a good example, to another rotary press or printing works. This function, unlike the ICC profile method(Note 5) which is described below, can perform color management easily. On the other hand, the method of bringing the characteristic of a rotary press close to those of an example rotary press by using a CMS color conversion engine or using the ICC profile of printing materials and the rotary press (called the "ICC profile method") is useful when a rotary press without this quality control system is used as the example rotary press and when colors are matched based on the characteristics stipulated by JCN (Japan Color for Newspapers) etc.

Note 3: CMS Color management system

Note 4: LUT Look up table (table of color characteristics)

Note 5: ICC profile Characteristic profile of a device made in accordance with the rules of International Color Consortium Association

4.2 Dampening water control function

This function detects the scumming of a non-image area by comparing the print density between a plate gap section and a page. When detecting scumming of the non-image area, this function automatically increases the amount of dampening water to get rid of the scumming. Thus, it prevents scumming from being generated when a rotary press stops operating, etc. and reduces paper being wasted at the next printing.

4.3 Print quality inspection function

This function not only carries out density control but also automatically inspects printing defects such as ink drops by comparing the actual print density with the reference print density in pixel units. Wasted paper is automatically discharged by outputting a waste ejection signal to the waste ejection carrier.

4.4 Plate-position checking

When printing starts and print contamination disappears, this function warns the operator that there is a high possibility that an error in the plate mounting is occurring when the target pixel density and the pixel density under print greatly differ, for example, when a certain density is detected in the non-image area.

5. Result and effect of verification

The results of an actual machine have already been verified under various conditions.

5.1 Improvement of reproducibility of printing quality and uniformity of coloring

(1) Reproducibility by the same rotary press

The dot gain and ink trapping of a rotary press vary according to environmental changes such as temperature and humidity and the difference in printing materials, and the printing characteristics of the rotary press fluctuate accordingly. This quality control system recognizes the fluctuations of the printing characteristics and automatically controls the coloring so as to keep it at almost the same level.

Concerning the reproducibility of printing characteristics, the results obtained by testing the image-based density control of the same rotary press seven times in total at different dates and times are shown in **Fig. 2**. Figure 2 shows the average color difference of 913 color patches on the test chart shown in **Fig. 3**. Dot gain and ink trapping fluctuate according to adjustment and printing materials.

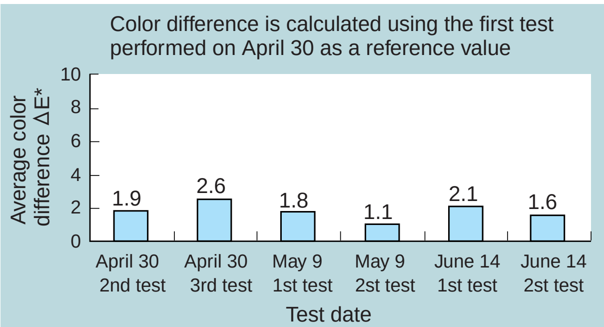

Fig. 2 Day by day color differences of the same rotary press
It can be seen from this figure that when this quality control system is used, day by day color differences maintain the relationship of $\Delta E^* < 3$ against the coloring of the first test performed on April 30.

Fig. 3 Test charts (patterns used for the test)

For example, ink trapping exhibits a variation of 10 to 15%, but controlling the ink trapping enables it to be kept within the average color difference of $\Delta E^{*}<3$. This accuracy was maintained for about one month after the test was performed, and this fact indicates the excellent reproducibility of this system.

Next, below are the test results which help the performance of this system to be easily understood. This printing test was implemented with the use of the test chart shown in Fig. 3 and with four rotary presses with different quantities of dot gain. The size of the dots was changed and different plates were made as shown in **Tables 1** and **2** so that the difference in the amount of dot gain between C plate and M plate appears when printing is done. The printed image data used reference data in which nothing was worked on the dot in all the aspects of the test.

In Table 1, the density of each printed page is controlled so that the solid printing density of each printed page is the same as the density of the reference page. The average color difference from the reference pages of the gray patch and the 913 color patches becomes larger as the differences in dot gain from the reference pages become larger. Shown in Fig. 2 are the test results obtained when image-based density control was performed. There are some discrepancies in the data, but the values obtained are within $\Delta E^{*}<3$ as a whole. The solid printing density differs from the density of the reference page, but almost the same coloring is obtained even if the dot gain of the ink is different in the same rotary press.

(2) Uniformity between printing works

When the 1 LUT method, which is a CMS supporting function of this system, is used even when the printing materials such as ink, rubber blanket and printing paper differ between printing works, this method brings the coloring close in all works.

The following two cases are now compared: a case where colors are matched with a solid printing density reference with the use of the test chart shown in Fig. 3; and a case where colors are matched by image-based density control based on the 1 LUT method employed by this system. **Table 3** shows the color difference from printed matter produced in K Printing Works (another printing works) using the 4T-front surface of F Printing Works as a reference value. When colors are matched with a solid printing density reference, the color difference from the 4T-back surface of F Printing Works is $\Delta E^{*}<2$, and the color difference from the other printing works is $\Delta E^{*} = 3$ to 5. On the other hand, when image-based density control is performed by the 1 LUT method, the color difference is $\Delta E^{*}<3$, so the uniformity of coloring is maintained between the different printing works. The color differences of the ink used in both printing works is shown in **Table 4**.

Table 1 Results obtained when only solid printing density is controlled against reference printed page

	Difference (%) of dot gain against reference page				Color difference (ΔE) from reference page	
	C	M	Y	K	Gray patch, etc.	color patch (mean value)
Rotary press A	-1	-1	±0	±0	2.2	1.9
Rotary press B	-3	-3	±0	±0	1.7	1.3
Rotary press C	+3	+7	±0	±0	3.9	2.3
Rotary press D	+9	+9	±0	±0	5.9	3.3

Table 2 Results obtained by testing the image-based density control of the MHI rotary press

	Difference (%) of dot gain against reference page				Color difference (Δ*E) from reference page	
	C	M	Y	K	Gray patch, etc.	color patch (mean value)
Rotary press A	-1	-1	±0	±0	1.5	1.8
Rotary press B	-3	-3	±0	±0	2.1	1.4
Rotary press C	+7	+7	±0	±0	1.9	1.5
Rotary press D	+9	+9	±0	±0	2.0	2.0

Table 3 Color differences of each printing works rotary press using 4T-front surface of F printing works as reference value

	4T-back surface of F printing works	1T-front surface of K printing works	1T-back surface of K printing works	6T-front surface of K printing works	6T-back surface of K printing works	Mean value
Color matching based on reference density	1.9	3.0	4.3	4.8	4.3	3.7
Color matching based on image-based density control	2.5	2.1	2.5	3.2	2.7	2.6

5.2 Reduction of wasted paper

After image-based density control was performed by this system in F printing works, the density convergence status was calculated for about one month. As a result of having verified it under various printing conditions, it was found that when automatic control was executed, the density converged on average in about 200 copies of a newspaper, though it depended upon the patterns used in the newspaper. On the other hand, when an operator adjusted the density, time was required to repeat the comparisons between some prints sampled from the folder and the proofs. As a result, the difference in time between the automatic control and the manual adjustment is obvious. This fact was remarkable when such fine adjustments as $\Delta E^*<3$ were necessitated. If this system is introduced, an improvement of quality as well as a reduction of wasted paper can be realized, particularly when an average color difference of $\Delta E^*<3$ is required.

5.3 Labor saving

Newspapers nowadays have a tendency to increase the number of pages and colors such as 40 pages and 16 colored pages, and high printing quality and reduction of wasted paper are required accordingly. Under such circumstances, the automation of color adjustment has been realized by this system, and great labor saving has been made possible, thus being able to meet such requirements. Besides, warnings are given for errors in mounting a plate, and defective pages which may unexpectedly occur during operation which undoubtedly helps reduce the number of operators.

5.4 Others

By introducing this system, newspaper companies can establish an environment where they can easily establish management standards. In other words, by managing colors, it becomes possible to evaluate and manage printing materials such as ink, paper and rubber blankets. This will advance the standardization of printing processes and will also stabilize the reproducibility of colors in newspaper printing.

6. Future development

MHI have put basic quality-control functions into practical use and have used them for actual printing for more than one year and MHI believe that the stability of this system has been certified. Furthermore, if this system is used, functions which estimate the amount of ink supply from the image area, and which estimate the amount of ink supply from the operation speed and pre-inking control data can easily be automatically produced according to the printing materials and the characteristics of the rotary press. Thus, by taking advantage of these capabilities MHI will further expand the range of applications of this system.

Table 4 Color difference of ink of F and K printing works

	Ink used in F printing works			Ink used in K printing works			Color differences of both inks			
	L	a	b	L	a	b	ΔL	Δa	Δb	ΔE*
C	58.4	-24.0	-29.2	57.6	-23.6	-25.9	-0.8	0.4	3.4	3.5
M	53.0	47.2	-2.7	53.3	46.7	-1.1	0.3	-0.5	1.5	1.6
Y	79.8	-6.0	59.5	77.0	-4.3	54.8	2.8	1.7	4.7	5.7
K	35.7	1.0	2.9	35.6	1.6	3.0	-0.1	0.6	0.1	0.6

7. Conclusion

In order to increase the efficiency of newspaper printing, it is necessary to optimize not only prepress processes such as CTP but also the whole process including press and postpress processes. MHI are convinced that DIAMOND EYE^{TM} will promote this to a great extent. In addition, MHI expect that to meet demands for high-quality newspaper printing by using DIAMOND EYE^{TM}, newspaper companies will be able to provide newspapers with uniformly-printed pages to a large number of areas, thus improving the satisfaction of their advertising clients.

Acknowledgements

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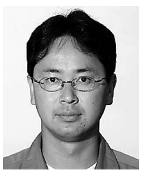
Norifumi Tasaka


Shuichi Takemoto


Takahide Toshito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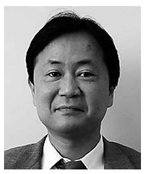
Ikuo Ozaki