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Development of Textile Printing System "Juana"

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Abstract:

The development of the textile printing system "Juana" using a color electrostatic plotter is described. A color printer for the Juana textile printing system was developed on the basis of the large-size single-pass color electrostatic plotter X2020, a major production item of Nippon Steel's high technology products division. Key technical points in the development were the effective utilization of the X2020 characteristics in the printer, development of recording materials, and the establishment of image processing technology.

1. Introduction

Nippon Steel introduced the basic technology of single-pass color electrostatic plotters from Synergy Computer Graphics of the United States, commercialized it with necessary modification to suit the Japanese market, and launched the single-pass color electrostatic plotter X2010 in 1989. Its higher version X2020 was brought into the market in 1992. The X2020 was originally intended for use in computer-aided design (CAD). When other markets were surveyed, however, there was found a strong demand for it from the textile printing industry. More specifically, the demand was for a new textile printing system that are fit for the small-lot production of diverse products. A new printing machine is indispensable for such a system, and the industry concerned evaluated the single-pass color electrostatic printer as the best suited for their need.

A new color electrostatic printer, designated the Juana printer, was developed on the basis of the X2020, and a Juana textile printing system was completed using this printer (see **Photo 1**).

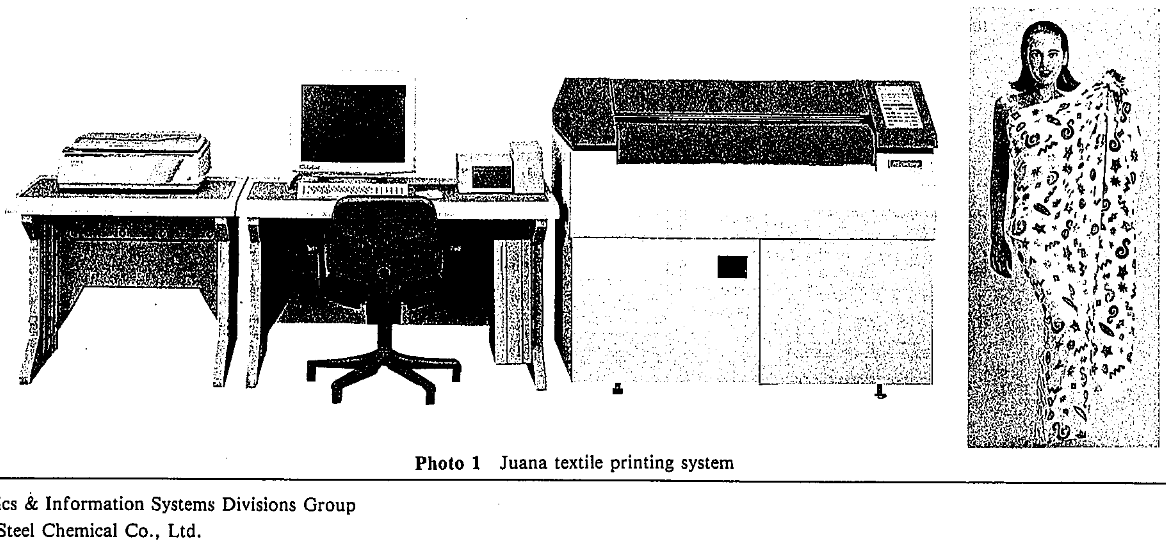

Photo 1 Juana textile printing system

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This paper outlines the Juana development in connection with the current situation of the textile printing industry. Major technical points in the system development were the maximam exploitation of the X2020 features in the Juana printer, development of recording materials and the image processing technology.

2. Present State of Textile Printing and Features of Juana Textile Printing System

Textile printing refers to the printing of patterns on cloth, and there are two main printing methods, namely, direct printing and transfer printing. The direct printing method applies dyes directly to the cloth. In the transfer printing method, a pattern is first printed on paper (transfer paper) using subliminal dyes, which is then transferred from the paper to the cloth under heat and pressure applied. The conventional transfer printing process uses plates for transfer paper printing as shown in **Fig. 1**, which makes platemaking an indispensable step. The platemaking step poses the following problems, which makes it disadvantageous particularly in the small-run production of diverse products:

(1) Long delivery lead time and low productivity
(2) High initial cost for platemaking
(3) Need for special platemaking know-how and skill

The Juana printing process, on the other hand, uses the Juana printer, which is a computer system output device. The platemaking step can be omitted from the production process to shorten the delivery lead time. The elimination of platemaking also provides cost savings and obviates the necessity of specialized platemaking skills. The above-mentioned problems can thus be solved entirely.

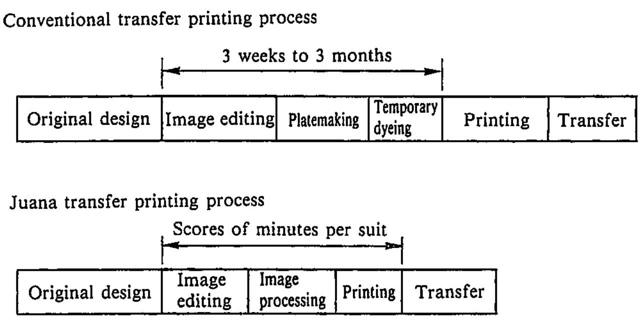

Fig. 1 Textile print production processes

3. Configuration of Juana and Textile Printing Process

3.1 Configuration of Juana textile printing system

The Juana textile printing system consists of a color scanner for reading an image, a personal computer for editing and processing the image, a full-color display for presenting the pattern, a hard disk drive unit for storing the pattern data, and a Juana printer for printing the pattern, as shown in **Fig. 2**. The Juana system covers up to the printing step as shown in **Fig. 1**, but does not include the transfer printing step, which is performed by users at their own plants.

3.2 Process of Juana textile printing system

(1) Original image design

The pattern is designed by the personal computer or by hand and is processed into the original image.

(2) Image editing

In the case of a manually drawn pattern, it is read by the color scanner (image reading). Then, the personal computer takes over the entire task thereafter. If necessary, a continuous pattern is generated from the original image. This step is characteristic of textile printing and is referred to as repeating. The pattern is then retouched. The colors of the pattern are changed, and additions and deletions are made as required all on the full-color display. The pattern design is thus completed (image retouching and editing).

(3) Image processing

The colors of the image read by the image scanner are presented in the RGB (red, green, blue) format, but the Juana printer reproduces colors in the CMYK (cyan, magenta, yellow, black) format. Therfore, the RGB format must be converted to the CMYK format (color separation). The image read by the color scanner has 256 levels of gradation. Since the Juana printer covers only two levels of gradation, pseudo-levels are created by image processing to reproduce the levels of the original image (pseudo-gradation).

(4) Printing

The processed image data are transferred to the Juana printer and printed on the transfer paper.

(5) Transfer

The pattern is transferred from the transfer paper to the cloth by heat and pressure on the transfer machine. This completes the entire process.

3.3 Advantages of single-pass color electrostatic printer

At present, electrophotographic color printers or ink-jet color printers are used in systems resembling the Juana system. The

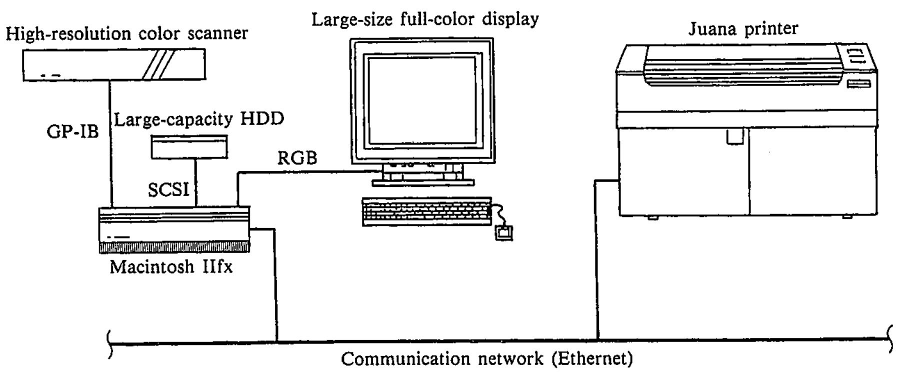

Fig. 2 Basic configuration of Juana textile printing system

electrophotographic color printing system is high in printing speed, but is limited in print size to A3 at most. It can be utilized for making small prints like proofs, but not for printing on wide cloth like dress fabrics. On the other hand, the ink-jet printing system can directly print patterns on wide cloth, but is low in printing speed (100 mm/min), requires post-treatment, and is poor in productivity. Neither system can meet the market need for producing wide continuous patterns in a short time.

The Juana textile printing system uses an electrostatic color printer. The Juana printer was developed on the basis of the X2020, Nippon Steel's principal electrostatic color plotter. The large-size single-pass color electrostatic printer can print wide continuous patterns (maximum width of A0) at a high speed (762 mm/min).

4. Development of Recording Materials for Juana Textile Printing System

The principle of recording on cloth by the Juana system is electrostatic. The electrostatic latent image formed on the transfer paper is made visible by a liquid toner and fixed to produce a textile printing transfer paper (Juana printing process). The cloth is placed on the recorded side of the transfer paper, the disperse dyes contained in the liquid toner are thermally sublimated to dye the cloth (transfer printing process). The basic properties required of the color liquid toner and electrostatic transfer paper as recording materials are as follows:

(1) Image quality comparable to that of commercial print cloth can be obtained.
(2) The handle of the cloth is not deteriorated by the heat transfer step.
(3) After the heat transfer of the pattern, the cloth can be easily separated from the transfer paper.
(4) Color reproducibility and fastness comparable to those of commercial print cloth can be obtained.

The development of the color liquid toner and electrostatic transfer paper for the Juana textile printing system and the quality of cloth printed by the system are described below.

4.1 Development of color liquid toner

A liquid toner has submicron dye particles dispersed positively or negatively charged in an aliphatic hydrocarbon solution of high dielectric strength. The realization of the Juana textile printing system called for the development of a new liquid toner suitable for textile printing.

The basic concept involved is the development of a textile printing color liquid toner that contains dyes applicable to polyester fabrics or polyester blended fabrics and that does not need the post treatment of the cloth after dying. Based on dyes equivalent to disperse dyes used on general print cloth, the new toner is composed of a material applied to obtain the charged state, a binder resin that can fix the dyes on the transfer paper at room temperature, and a charge control agent to control the polarity and charge amount of dye particles.

For the subliminal disperse dyes, three primary color and black base dyes that provide bright colors and excellent dying properties and are suited for color image reproduction were selected and adjusted so that the dye particles can be positively charged when dispersed together with the binder resin in the solution.

The binder resin must be high in heat resistance, must not hamper dye sublimation during heating, and must adhere to the transfer paper. A new resin was synthesized to obtain these binder resin properties.

The charge control agent must have such an amount of charge that toner particles can be positively charged uniformly and sufficiently saturate to develop an electrostatic latent image. It must also have the function of maintaining charge stability for a specified length of time. A special material that does not interfere with color reproducibility was selected, and a charge control agent that can practically satisfy the requirements was developed.

The above-mentioned basic components were mixed, saturated, mutually adsorbed, ground into particles, and dispersed in appropriate proportions by color in the aliphatic hydrocarbon solution to produce the toner.

4.2 Development of electrostatic transfer paper

Electrostatic transfer paper is a medium used in electrostatic printing. It is a special type of paper on which an electrostatic latent image can be formed by controlling the high voltage applied to nib-shaped electrodes arranged on the Juana printer head according to the presence or absence of record information and by ionizing oxygen in air through the discharge phenomenon.

The electrostatic transfer paper is similar in basic composition and properties to color electrostatic recording paper used in general CAD applications. Excellent solid image quality and no transfer of paper components to cloth during heat transfer are additionally required of the transfer paper for the Juana textile printing system.

The transfer paper developed for the Juana textile printing system has the discharge sensitivity and latent image potential homogenized for better solid image quality. The record layer resin is provided with heat resistance, and the transfer paper components and the toner binder resin are designed not to be transferred to the cloth on which the pattern is being printed.

4.3 Hue reproducibility and color fastness

The image quality of cloth printed by the Juana system is nearly the same as commercial print cloth. The hue reproducibility of the cloth printed by the Juana system is generally comparable with that of commercial print cloth on a CIE chromaticity diagram (L*a*b* color scale) as shown in **Fig. 3**. The color fastness requirements of print cloth are as given in **Table 1**. Thus, the cloth printed by the Juana system has performance properties that are similar to those of commercial print cloth.

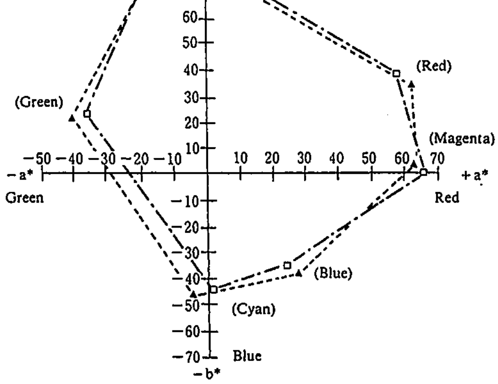

Fig. 3 Hue reproducibility by CIE chromaticity diagram (hue reproducibility range in L*a*b* color scale)

Table 1 Color fastness test results

Evaluation item		Test method / JIS standard	Satin cloth / Art mix pattern				Crepe de Chine / Pearl floral pattern			
Color fastness to light (20 h)		L 0842	C	5			C	5		
Color fastness to perspiration (method A)	Acid	L 0848	C	5	S	5	C	5	S	5
	Alkali		C	5	S	5	C	5	S	5
Color fastness to washing (method A-2)		L 0844	C	5	S	5	C	5	S	5
Color fastness to dry cleaning		L 0860	C	5	S	5	C	5	S	5
Color fastness to rubbing (type II)		L 0849	C	5	S	5	C	5	S	5
Color fastness to sublimation (method B)		L 0879	C	3	S	1	C	4	S	2

Notes:
1) C = Discolaration, S = Stain. Maximum degree of evaluation is 8 for color fastness to light and 5 for other color fastness properties.
2) All cloths are 100% polyester.
3) Heat transfer conditions: 195°C, 2.0 kgf/cm^2, and 30 s.

5. Development of Image Processing Technology

5.1 Need for image processing

The color intensity that can be represented by the dot drawn by each nib on the Juana printer can assume only two levels (or on and off states). Intermediate levels cannot be represented. The data read by the scanner and the data handled by the computer have 256 levels of color intensity. Patterns read by the scanner or designed by the computer must be converted to two levels of color intensity before they can be printed with the Juana printer. This conversion is called thresholding.

5.2 Pseudo-gradation representation

In thresholding, a certain threshold is established to produce two-level images from text, figures, and other features that essentially need no gradations. This method, however, cannot be applied to patterns and photographs for which intermediate levels are important.

The Juana system introduced a technique, called the pseudo-gradation representation method, that represents intermediate levels according to the distribution density of on and off dots. Among common such methods are the error diffusion method, the dithering method, and the screen method that is frequently used in printing and other applications. The error diffusion method thresholds an input image at a given value, diffuses any thresholding error between subsequent pixels, and reduces the average intensity difference between the input image and the output image (see **Fig. 4**). With the dithering and screen methods, the value for thresholding the input image is established with an m × n matrix. The matrix is repeatedly used to produce the output image (see **Fig. 5**). Images of various characteristics can be produced by changing the way the matrix is established.

The pseudo-gradation representation method attempts to reproduce color intensity in two levels and cannot completely reproduce colors over the entire intensity range. For example, the error diffusion method produces a characteristic dot pattern in the low-intensity region and degrades the image quality. The dithering and screen methods are advantageous in that color intensity representation is stable in the low-intensity region, but disadvantageous in that a characteristic threshold matrix pattern occurs across the entire image. When developing the Juana textile printing system, Nippon Steel solved these problems by developing an original method that utilizes the advantages of two algorithms, that is, the dithering or screen method and the error diffusion method, and by mixing the two thresholding methods in the medium-intensity region.

5.3 Tone correction

The intensity gradation produced by the pseudo-gradation method should theoretically become linear, but when image density on actual cloth is measured with an optical densitometer, there occurs a deviation to a slight degree. This deviation is attributable to the variation of dot shape. The dot shape is considered to vary according to the following factors:

(1) Type of cloth (type, size, and weaving method of fiber)
(2) Transfer conditions (temperature, time, and pressure)
(3) Juana printer service environment (temperature and humidity)

To counter these variations, parameters were established and made available to users. If all parameters are made public, users will take some time before they can master the Juana system. It was therfore decided to preset the standard cloth, standard transfer conditions and standard environment and to make primary correction to the deviation between the calculated and measured density values by preparing a gamma table (correction correspondence table).

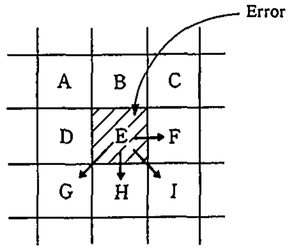

Fig. 4 Error diffusion method

Dithering method (Bayer type)

1	9	3	11
13	5	15	7
4	12	2	10
16	8	14	6

Dithering method (Fattening type)

14	10	6	15
5	1	2	11
9	4	3	7
13	8	12	16

Fig. 5 Dithering method matrix

6. Conclusions

The Juana textile printing system with a single-pass color electrostatic printer has been described above. The single-pass color electrostatic printer can be used also as output device in other systems. We will continue our efforts to keep informed with the market needs and to develop systems accordingly.

7. Acknowledgment

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