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High Resolution LED Print Head

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Abstract

A 1200 dpi LED print head requires high precision light quantity compensation technology to adjust the dispersion of light quantity by an LED light sources and optical system. In conventional light quantity compensation, an area has been calculated assuming that the image formation shape of the LED is a circle. This time we developed a high precision compensation technology for the distortion of an image by measuring the area of an ellipse using two sensors that have slits perpendicular to each other. With this technology, we implemented a high resolution LED print head with uniform density.

1. Introduction

In a 1200 dpi LED print head, 1200 dpi LED arrays, the light sources of the print head, have already been implemented by Zn solid phase diffusion technology[1]. For LED print heads, luminous energy compensation technology combined with the rod lens required for image formation to control light intensity dispersion is important.

This paper first presents an overview of an LED head, describes the factors which influence image quality, and finally describes the light intensity compensation technology that we developed for a 1200 dpi LED head.

2. Overview of LED head

Photo 1 shows the appearance of a 1200 dpi LED head and LED array unit.

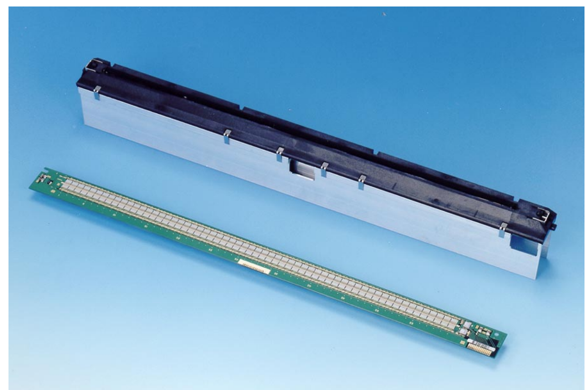

Photo 1: 1200 dpi LED print head and LED array unit

2.1 Optical operation

As Figure 1 shows, the LED head consists of an LED array unit, rod lens array, and a holder that supports the LED array unit and rod lens array. The A3 size 1200 dpi LED array unit is a row of 15360 LEDs with 21.2 μm spacing. The rod lens array has 2 rows of graded-index lenses (diameter: approx. 0.6 mm), with 500 lenses in each row. The rod lens array and LED array face each other. The rod lens has a characteristic to form an erect image of a light source (LED) at the same size on the image drum. Light emitted from one LED goes through several rod lenses to form an image.

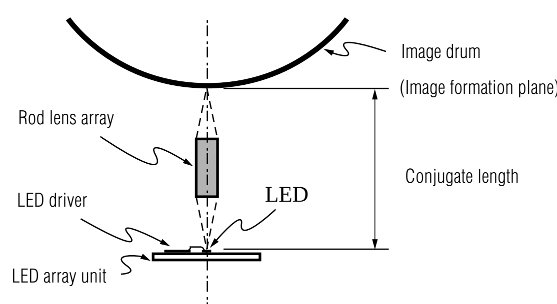

Figure 1: Basic structure of LED print head

2.2 Electrical operation

Each LED emits light by the current supplied by the respective LED driver (one LED driver for one LED). A driver has a light intensity compensation function[2]. Based on 4 bits of compensation data written to EEPROM that is built in to the head, current to be supplied to an LED is controlled at 16 levels, in a -14% to + 16% range, to compensate emitting light intensity. Density dispersion is minimized by setting compensation data to be written to EEPROM at an optimum level.

3. LED head and image quality

3.1 Image formation area

Figure 2 shows light intensity distribution on an image forming plane of an LED head. In Figure 2, the image formation area is a cross-section of a profile that is sliced horizontally at a certain threshold value determined by the sensitivity of the image drum and by other factors. When two straight lines are printed at 600 dpi, for example, the two straight lines cannot be separated and are printed as one line if the image formation area is large. When many grayscales are required with pixels as small as possible, as when printing a photograph, the required number of

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grayscales cannot be acquired if the image formation area is large. In order to decrease density unevenness using gray filling printing, the image formation area must be uniform for 15360 LEDs. The following are the factors at the LED head side which influence the image formation area on the image drum.

1. LED
   When conditions of the optical system are the same, the image formation area increases as the light intensity of the LED increases. Also as the area of the light emitting section of the LED increases, the image formation area increases.
2. Rod lens array
   Resolution of a rod lens indicates the capability of how accurately light emitted for a point is formed as an image of the point. As resolution becomes higher, the closer two points can be separated. If resolution of the rod lens is low, light from the light emitting section spreads, and the image formation area increases.
3. Assembly accuracy of head
   If the space between the light source and image formation plane deciates from the design value due to poor component accuracy and assembly accuracy of the LED head, resolution will drop and the image formation area will increase.

   Dispersion of the image formation area appears as density unevenness when printed, affecting printing quality considerably. To eliminate density unevenness, the dispersion of the image formation area must be controlled to 2% or less. Each factor that affects the image formation areas must be managed independently for manufacturing, so that dispersion is minimized. However, it is very difficult to control the dispersion of image formation areas caused by the combination of each factor in the head assembly stage to 2% or less, simply by managing individual characteristic values. Therefore it is necessary to measure the image formation area and to set light intensity compensation data based on the measurement result.

4. Light image compensation

Setting light intensity compensation data based on measurement of the image formation area is called "light image compensation". To unify image formation areas, an image formation area must be accurately measured. To perform this, a two dimensional sensor, such as a CCD, can be used. However, this is not appropriate for mass production because there are 15360 LEDs in the head, and even if it takes 0.1 second per dot, 25 minutes or more will be required, so another method must be used to measure the approximate area at high-speed.

4.1 Conventional light image compensation

The conventional light image compensation for a 600 dpi LED head is described first. Figure 3 shows the conventional measurement method.

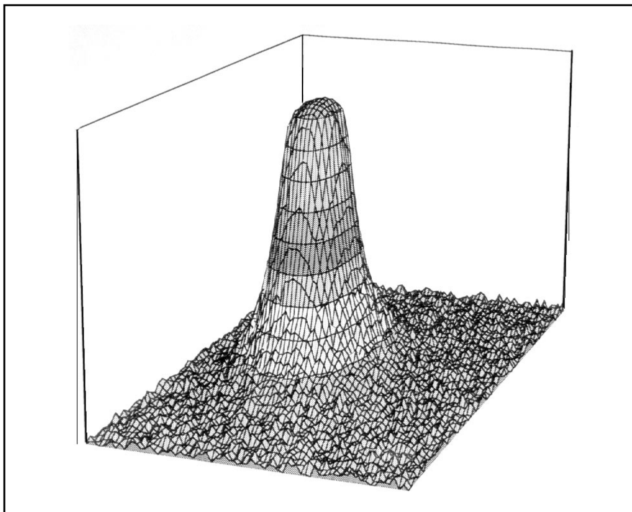

Figure 2: Light intensity distribution on image formation plane

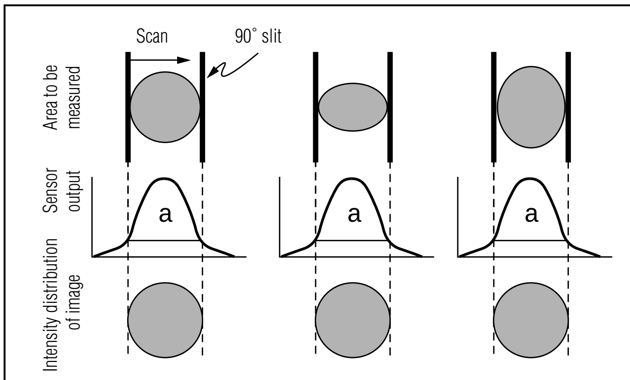

Figure 3: Illustration of measurement by 90° slit

A photo diode is used for the sensor, which scans LED arrays in the array direction. The photosensitive section of the photo diode is covered with a mask which has a slit type opening. The size of the slit is 5 µm in the scanning direction, and 5 mm in a 90° direction from the scanning direction. By scanning the image formation plane of the LED head using the sensor with a slit, light intensity distribution on the image formation plane is measured. Output of the sensor is a one dimensional value when the actual light intensity distribution is detected with a 5 µm space vertical to the LED array direction. The width of the image a is determined from this output with an appropriate threshold value, and the area is measured assuming that the image is a circle.

4.2 Shape of formed image

The shape of a formed image is now the issue. In some cases, an image is deformed as an ellipse, mainly because of the shift of the optical axis of the rod lens. In the case of a 1200 dpi LED, where the area of the light emitting section is much smaller, the influence caused by the shift of the optical axis of the rod lens is greater than conventional LEDs. With a conventional 90° slit measurement, the same

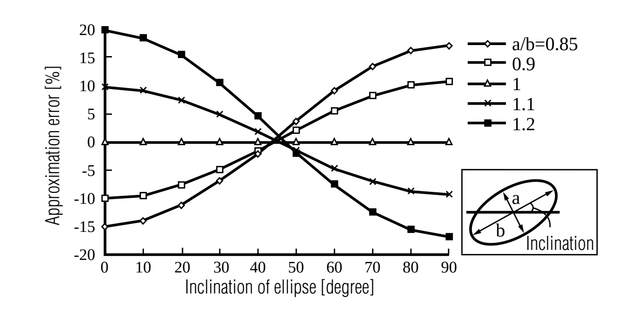

Figure 4: Inclination of ellipse and approximation error (90˚ slit)

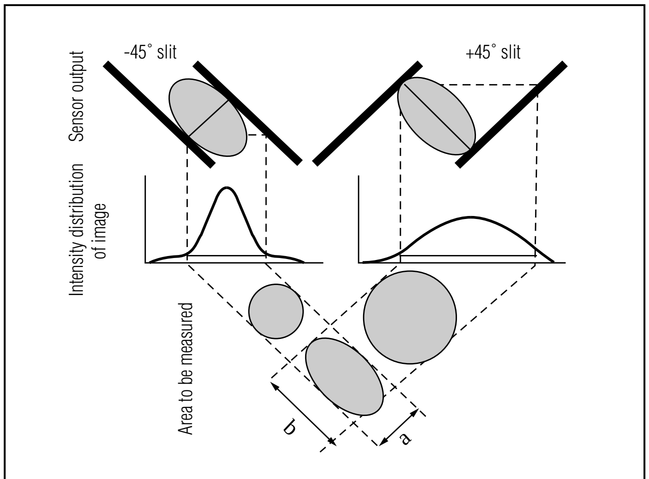

Figure 5: Illustration of measurement by ±45˚ slits

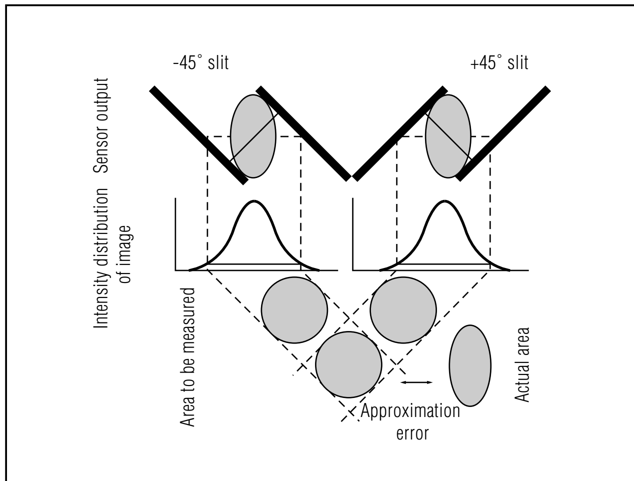

Figure 6: Approximation error by ±45˚ slit

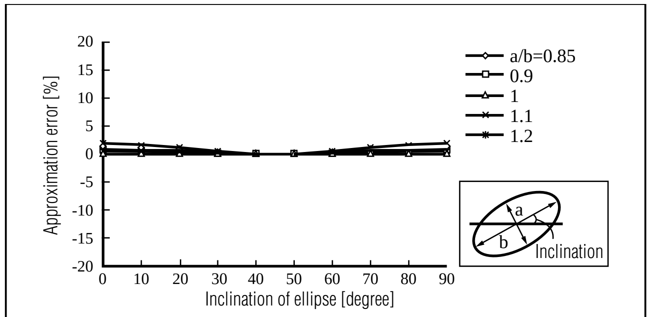

Figure 7: Inclination of ellipse and approximation error (±45˚ slits)

result is output for both a normal shape (circle) and an ellipse, which cannot be distinguished from each other. Figure 4 shows the relationship of the inclination of an ellipse and the approximation error when the ellipse is approximated to a circle. When inclination is 0° and 90°, error is high. The approximation error increases in proportion to the flattening ratio.

4.3 ± 45˚ slit measurement

This section describes the light image compensation method that we developed this time to approximate the area of an image more accurately. Two sensors are used for the method of this development. As Figure 5 shows, one sensor has a slit mask which is inclined -45° from the scanning direction, and the other has a slit mask which is inclined + 45° from the scanning direction (perpendicular to the above mentioned slit). By scanning with these sensors, the image formation areas of all dots of the LED head are measured. If the space of slits from the point where light intensity exceeds the threshold to the point where light intensity becomes lower than the threshold is a in the minor axis and b in the major axis, then the image formation area is (x a x b. Then the light intensity compensation value is calculated from the ratio between the mean value of image formation areas of all dots and the image formation area of each dot, and the result is written to EEPROM. Even with this measurement using ± 45° slits, errors occur, depending on the position where the slit and image contacts, as Figure 6 shows. Figure 7 shows this approximation error. Approximation error is highest at inclinations 0° and 90° (in the case of Figure 6), and is 2% or less in the range of flattening ratio 0.85 ~ 1.2.

5. Compensation result

Figure 8 shows the deviation from the mean value when the diameter of a formed image before compensation is measured with a 90°, + 45° and -45° slit. Compared with a 90° slit, dispersion of measurement values is large with +45° and -45° slits. This is because +45° and -45° slits can detect the distortion of images which a 90° slit cannot. In the section at the right of the graph, measurement results by + 45° and -45° slits are reversed, indicating that the image is distorted, becoming longer in the + 45° direction. Figure 9 shows the dispersion of image formation areas by two sensors with + 45° and -45° inclination slits before and after compensation. After compensation, dispersion is within ± 3%. Figure 10 shows the printing result by a 1200 dpi LED printer adopting this compensation method.

It takes approximately 30 seconds for measurement and compensation, which is acceptable for mass production.

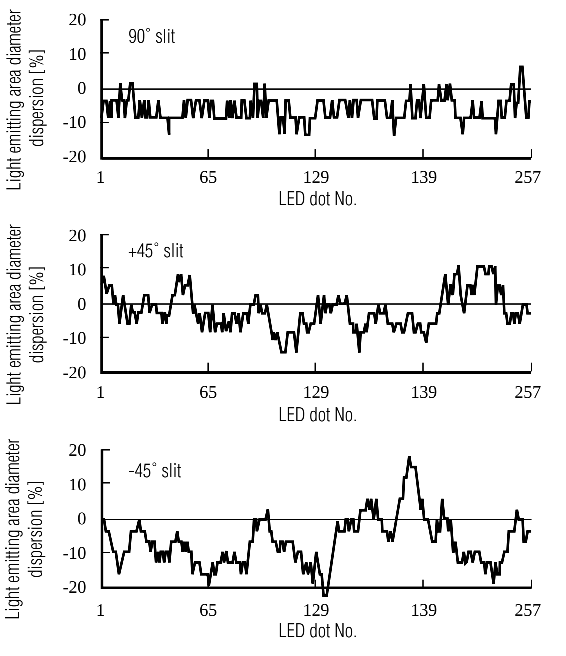

Figure 8: Result of slit measurement

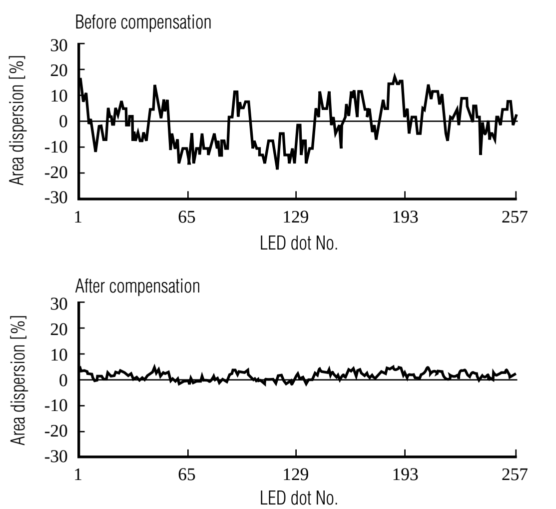

Figure 9: Area dispersion before and after compensation

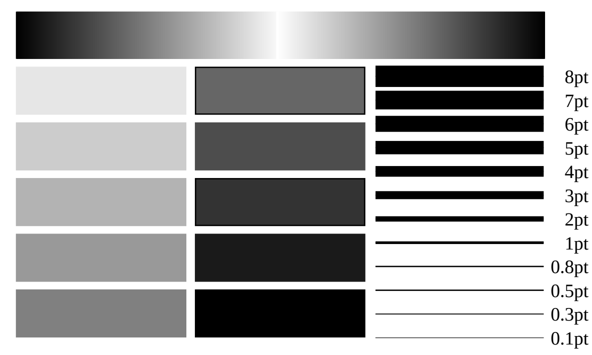

Figure 10: Print sample of 1200 dpi LED printer

6. Conclusion

The compensation method that we developed this time made highly accurate compensation for 1200 dpi possible. However, an elliptic image can be compensated for an area, but not for shape. Also images are not always distorted to an ellipse shape. There are still improvements that remain. To achieve higher quality printing results, we first must work on improving accuracy of individual components. At the same time, in order to accurately measure an image formation area, we would like to work on area measurement by two dimensional sensors, which could not be used thus far because of processing speeds.

7. References

1. Higaware et al: "Development of Zn solid phase diffusion technology," *Oki Kenkyu Kaihatsu,* 173, 64, 1,(1997): 39 ~ 42.
2. Tajiri et al: "Light intensity compensation type 600 dpi / A3 LED head," *Oki Kenkyu Kaihatsu,* 173, 64, 1, (1997): 27 ~ 30.