Development of Compact LED Head

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In recent years, printer manufacturers have each introduced xerographic printers that employ LED head as an optical writing light source. OKI has utilized the LED head since the beginning of its xerographic printer development, and taking advantage of the LED head's characteristics, supplied to the market numerous tandem-type color printers that are compact, high-speed and high-quality. This article describes the design changes made over the course of the LED head's development and optical measurements/corrections that are essential for producing high-quality images.

LED Head Design

As shown in **Figure 1**, basic components of the LED head are the LED array, which is a number of light emitters arranged in a single column, lens unit to focus light emitted from the LED array on to the photosensitive drum, board on which the LED array is mounted, and casing that houses the entire unit.

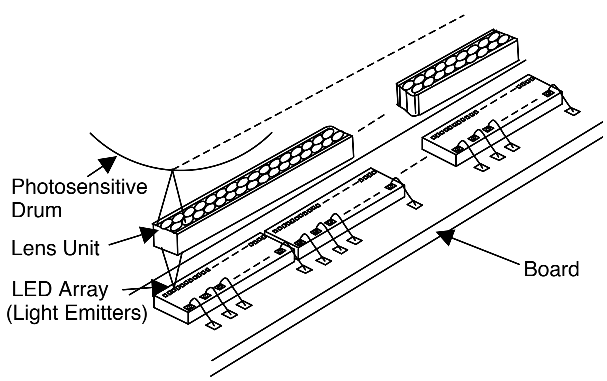

Figure 1. Basic LED Head Design

Light emitters produce light according to signals from the printer. Light is focused on to the photosensitive drum, and sections of the drum where the light strikes are neutralized. Toners adhere to the neutralized sections to form an image. LED's resolution determines the resolution of the printer. The 600 dpi (dots per inch) resolution (42.3μm dot pitch) and 1200 dpi resolution (21.2μm dot pitch) are the two mainstream LED arrays.

The lens unit focuses the emitted light from the LED array on to the photosensitive drum. Accuracy of the focus determines the sharpness of the printer's image. Lenses used in the LED head have very short focal length, as distance from light emitters to the focus point on the photosensitive drum is about 9mm. Therefore, effect of diffraction, a basic behavior of light, is almost non-existent enabling sharp images to be produced. Furthermore, this shortness allows a compact exposure source to be placed near the photosensitive drum resulting in a smaller printer chassis.

However, the currently used lenses have a narrow high-resolution focal range. Thus, high precision is required in positioning the focus direction. Position must be accurate to within micrometers over a length of 20cm for A4 size and 30cm for A3 size. That is, the long lens unit and LED array must be mounted without bending. Here is where the difficulty in LED head production lies.

The casing requires dimensional accuracy as well as rigidity over the length of the LED array to ensure straightness. A method to mount the board containing the lens unit and LED array must also be devised.

Figure 2 shows the cross-section of a LED head, which first began full-scale mass production in the late 1980's. At that time, the board mounted with the LED array was sandwiched between drawn aluminum and mold. Drawn aluminum ensured the straightness of the board and acted as a heat sink. Pressing the positioning contact surfaces provided at both ends of the lens unit against the contact surfaces in the mold secured lens position and simplified assembly. In those times, printer resolution

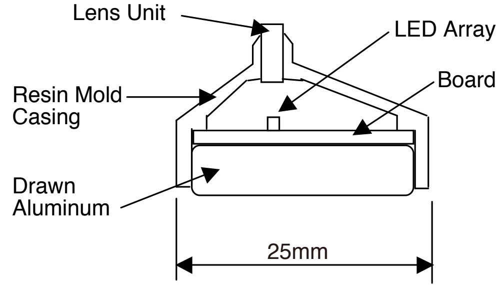

Figure 2. Initial Mass Produced LED Head

was a low 300dpi (84.6μm dot pitch), and since character printing was the main objective, print quality was sufficient even with some degree of error in the drawn aluminum's and lens unit's straightness.

Cross-section of the first LED head employed in a tandem A3-size 1200 dpi color printer is shown **Figure 3**. In consideration of cost, the board is inserted between the sheet metal and mold. For straightness accuracy, lens unit is aligned straightly along a jig then secured to the casing with adhesive. To achieve high precision implementation, wedge-shaped sliders were placed at each end of the casing. As shown in **Figure 4**, the sliders are used to adjust the distance of the lens unit from the photosensitive drum, so that focus point can be properly positioned on the drum.

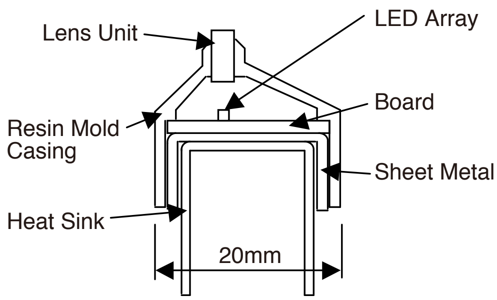

Figure 3. A3 1200 dpi Print Head

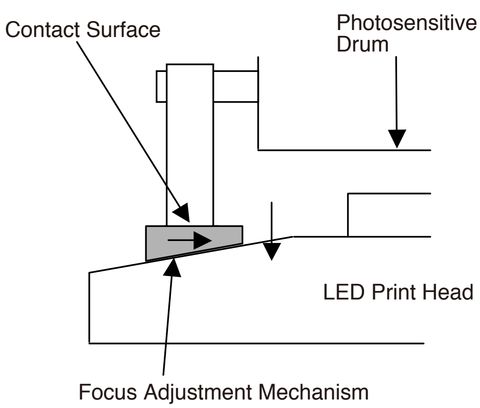

Figure 4. Wedge-Shaped Focus Adjustment Mechanism

Current in the order of milliamps flows through each dot of the light emitting LED. In case of an A3-size 1200 dpi LED, number of dots totals approximately 14,000, and entire current is of ampere order. To enable this current to flow, pattern width for power becomes necessary, and a board with a reasonable width was required. Furthermore, a heat sink was added to the sheet metal for heat dissipation.

In this design, jig accuracy ensures straightness of the lens unit, but straightness of the LED array's focus direction is determined by the sheet metal flatness. However, the required flatness could not be obtained with normal sheet metal processing. Therefore, a special correction process was added.

Advancements in LED array development have remarkably improved luminous efficiency, and integration of LED and its driver IC using epi film bonding (EFB) technology[1)] developed by OKI Digital Imaging Corporation has led to significant reduction in size. **Figure 5** shows the cross-section of an A3-size 1200 dpi LED head that utilized EFB technology. In this design, the casing is composed of die-cast aluminum. To achieve accurate board flatness, cutting work was performed on the surfaces that make contact with the board. Focus position is adjusted using eccentric cams attached at both ends of the casing as shown in **Figure 6**.

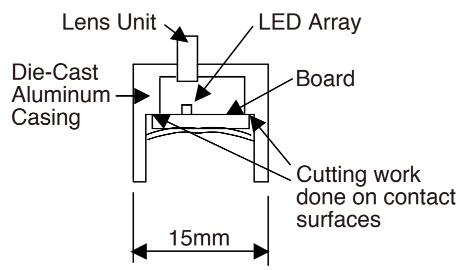

Figure 5. Die-Cast Aluminum LED Head

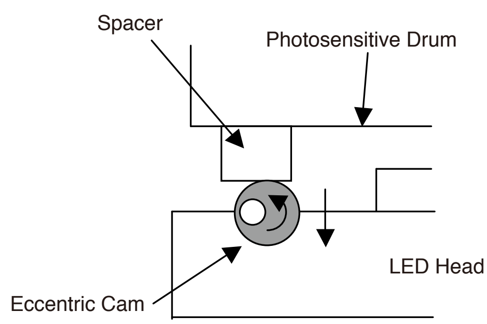

Figure 6. Focus Adjustment using Eccentric Cam

Additionally, spacers were placed directly on the photosensitive drum to act as a contact surfaces with the eccentric cams. This kept the distance between LED head and photosensitive drum highly constant substantially improving focus accuracy. Furthermore, better luminous efficiency reduced drive current and contributed to narrowing board width and reducing heat sink.

Dimensional accuracy of the die-cast aluminum casing can be obtained with cutting work, but the additional work adds cost. Therefore, in the subsequent design, sheet metal was used for strength and flatness of the contact surfaces was ensured by placing sheet metal inside the resin mold to form an integrated resin mold[2]. This method eliminates the costly cutting work and reduces the cost of the casing.

With the method described so far, the jig maintains lens unit straightness, but since the board is fixed against contact surfaces, the LED array straightness is affected by surface accuracy of the contact surfaces. In the latest method shown in **Figure 7**, board straightness is also maintained by the jig. Moreover, focus point adjustment is done by adjusting the lens unit and board bonding positions with sheet metal casing using the jig enabling the achievement of a high-precision assembly.

Although this method necessitates ingenuity and precision in jig manufacturing, parts cost is the least expensive since inexpensive sheet metal, which does not require special accuracy, can be used. Sufficient rigidity can be obtained by ensuring a proper height dimension. During assembly, applying the same pressing force as when mounting to the printer will enable the deformation effect from the force at time of printer mounting to be absorbed. For this reason, it was possible to achieve a 10mm wide LED head even in an A3 size. Furthermore, since focus is adjusted during assembly, eccentric cams and other parts used for adjusting focus are eliminated.

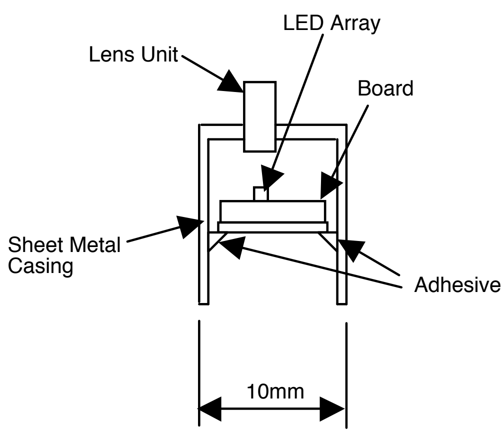

Figure 7. Latest A3-Size LED Head

Focus-positioning contact surfaces on the printer side are required to produce precise distance from photosensitive drum to LED head. To do so, dimension is taken from the photosensitive drum's axis or spacers are placed on the photosensitive drum. Placement of spacers depends on the locations of the contact surfaces, which are limited by the drum length and surrounding components. Contact surfaces on the LED head side must also comply with those limited locations. Focusing mechanism such as the eccentric cam outfitted for a specific printer is unusable in others. However, by eliminating the focusing mechanism, contact surfaces can be freely located within a certain range (red dotted line in **Figure 8**) at both ends of the lens unit, and LED head using the same casing is mountable in different types of printers. Additionally, making the contact surfaces of the jig used during LED head assembly the same as the contact surfaces of the respective printers, different types of printers can be assembled while accurately adjusting focus even with the use of the same casing.

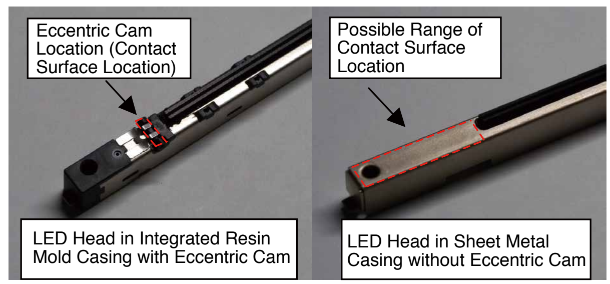

Figure 8. Contact Surfaces with and without Eccentric Cam

As was described, the latest LED head can be assembled without being affected by the precision of the components, thereby reducing the cost of materials. Using the same casing for LED heads of different type printers allows the use of common parts further reducing cost.

LED Head Measurements and Correction Technique

LED head is composed of numerous LEDs arranged on a chip, and their variations require control. Likewise, the lens unit used as the imaging optical system is formed from multiple lenses, and their variations are an issue.

Initially, when mass production began in the late 1980's, LEDs themselves, built on compound semiconductors, showed large variations in luminous efficiency. Since adequate correction techniques were also not available, light intensity of each LED dot was measured for variation calculation and selections were made to ensure quality. Advancements in compound semiconductor manufacturing technology and development of an IC driver, which is capable of correcting variations to within 1% for each dot, now allows variations in LED luminous efficiency to be corrected with high degree of accuracy. Light intensity is measured by placing a photo sensor at the imaging position of LED array, which lights up one dot at a time, and observing the sensor output. During initial development, light intensity measurement took tens of minutes for a single LED head. With improved measuring and data processing techniques, light intensity measurements of some 14,000 dots in an A3-size 1200 dpi LED head can be accomplished in matter of seconds.

Variations of the lenses cause variations to occur in the image produced by the LED array (light intensity distribution) on the photosensitive drum resulting in uneven toner density and poor print quality. This variation in light intensity distribution can be measured by scanning the imaging position with the photo sensor. An example of such data obtained from scanning the LED array in the direction of arrangement is shown in **Figure 9**. This figure shows light intensity distribution in the main scanning direction at the imaging position of the LED head repeating a one dot ON, seven dots OFF light pattern. Each bell curve represents one ON LED. Light intensity of one dot corresponds to the area below the curve. The printer's photosensitive drum is exposed to this light intensity distribution and toners adhere accordingly to form the print image. Light intensity from each dot can be controlled by correcting the current supplied from the driver IC. That is, area of each bell curve can be corrected. However, different bell curve shapes will result in different toner adhesion even if the areas are the same. From the general theory of xerographic process used in the printer, if toner is considered to attach to locations where light intensity distribution exceeds a certain threshold, then section where width of the threshold is narrow will cause the location of toner adhesion to be narrow resulting low print density. On the other hand, if width of the threshold section is wide, print density becomes high.

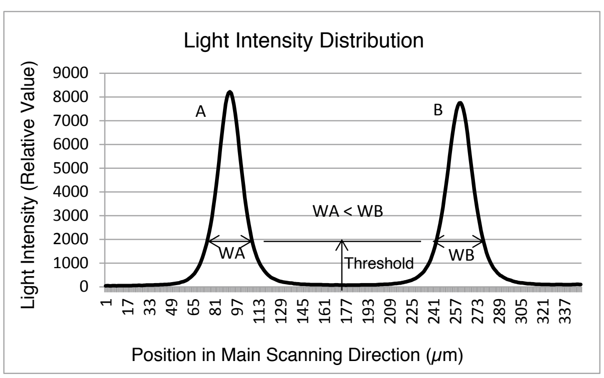

Figure 9. Light Intensity Distribution of LED Head

Although bell curve A and B have the same area, at the threshold height, curve width WA is less than curve width WB. Thus, toner adhesion of A is less than toner adhesion of B. That is to say correcting light intensity to a constant level does not correlate with constant toner adhesion, and variations in print density cannot be suppressed. Toner adhesions will become the same if the curve shapes can be made identical. However, lens characteristics and positional relationship with the LED array determine the curve shape making it impossible to correct each dot. Only correction that can be made to each dot is the light intensity (curve area).

Therefore, light intensity is adjusted by predicting the toner adhesion from the curve shape. Toner adhesion is expected to be less with curve A, so light intensity of the corresponding dot is made higher to increase the amount of adhering toner. Oppositely, curve B is expected to have more toner adhesion, so light intensity of that corresponding dot is decreased to lessen the amount of toner. As described, amount of toner adhesion is predicted from the curve shape (light intensity distribution) and light intensity is raised or lowered accordingly for a uniform toner adhesion, thus achieving quality printing without unevenness in toner density.

Furthermore, toner adhesion varies depending on the kind of printer. For this reason, a different correction method is used on the same LED head and correction that matches each printer is performed, thereby realizing a LED head with high print quality.

As described above, the latest LED head ensures high focus accuracy while using low cost components, and it is designed to be used in various types of printers without alteration to the main head unit. Additionally, due to advancements in correction techniques, the head provides sufficient quality for use as an exposure source in high-quality color gradation printers. ◆◆

■ References

1) M.Ogihara et al, "LED array integrated with Si driving circuit for LED-printer printhead", Electron, Lett., 42 (15), pp.881-883, 2006

2) Koichiro Aizawa, Norio Nakajima, "Advanced LED Printhead", OKI Technical Review, October 2010/Issue 217 Vol.77 No.2, pp.42-45

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