Thermal analysis technology of full color thermal printing

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Abstract

We examined simulation of full color thermal printing.

In NIP22, we reported thermal head design by automatic iterative calculation of two-dimensional heat conduction analysis. We developed the thermal head with small variation and low power consumptions by applying Taguchi Method to the parameter optimization.

This time, by enhancing an analytical model to three dimensions, we became possible the simulation of the temperature distribution not only in direction of paper transportation and depth but also in in-plane each layer. As a result, the relation between the structure of thermal head and the internal temperature distribution of paper was clarified. We examined the thermal head structure that is appropriate for thermal print by using this analytical model.

Introduction

Direct thermal printing that uses the thermal paper is a technology that has been generally used for some time. It became easy to acquire the image data by the spread of the digital camera in recent years, so opportunity for printing has increased. As for direct thermal printing, high-quality print came to be requested. In black-and-white print, the stamp with photograph, the company logo, and the image are printed. There is the full-color paper like TA (Thermo Autochrome) with multi color developing layer fixed by ultraviolet light and new full-color direct thermal printing medium that Polaroid announced with NIP21.

We made three-dimensional analysis model including the paper and the thermal head, and examined the thermal head structure for high-quality in thermal print with such a thermal paper. We have found the structure that is appropriate for high-quality print from the examination by simulation and confirmed actually effective by head trial manufacture.

3D analytical model of thermal head

We have modeled the head and paper in the section and simulated so far. For such two-dimensional model, we were able to analyze the thickness of the each layer that composed the head and the paper as a parameter, and it was enough for examination of the power saving etc. Moreover, because the number of elements is little, it is suitable for the analysis that needed iterative calculation like optimization. However, because the direction of in-plane is not considered, the temperature distribution by the heater at constant intervals is disregarded. Therefore, it is impossible to analyze the influence that the temperature distribution in the direction of the in-plane gave to the printing quality. It is important to know the temperature distribution in the color development layer to improve printing quality, so we made three-dimensional analysis model of the thermal head and paper.

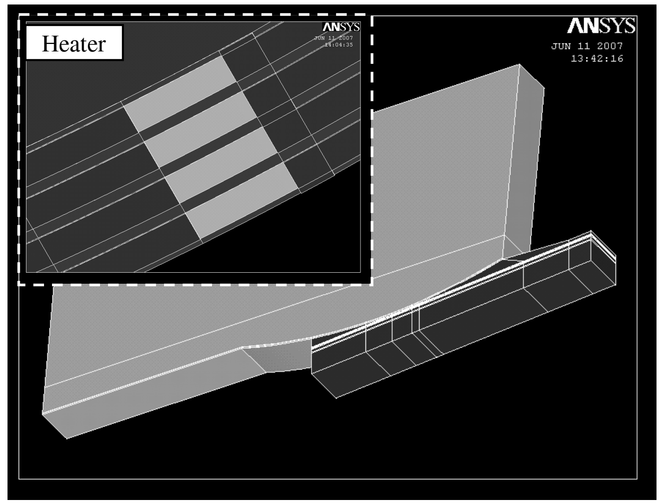

***Figure 1**. 3D analytical model*

To apply our automatic optimization method, analytical model was made by the text data based on an analytical model of NIP22. Figure 1 is three-dimensional model of the thermal head and the paper made this time. In the dashed line, internal structure around the head heater was shown. Because dot gap and angle of heater were newly made a parameter about the head, when the width of dot gap is specified, the relating input value is automatically changed. The paper to be analyzed is black-and-white paper with single heat sensitive layer and full-color paper with three color development layers (Yellow, Magenta and Cyan). As for the black-and-white paper, heat sensitive layer containing leuco dye, developer and sensitizer is coated on base paper, and these melt by heat from a thermal head. As for full-color paper, it has three heat sensitive layers (Y, M and C) that the sensitivity is different, and the layer of Y and M are fixed by ultraviolet light for TA. Image is formed with the repetition of color developing and image fixing.

Content of FEM analysis

We analyzed the relation of head structure and temperature distribution of color development layer by using this analytical model. Examination result of the dot gap width and the heater angle is shown. In each analysis, value of table 1 was used as a common condition.

Table 1: Head specification

Heater length	90 [um]
Dot pitch	300 [dpi]
Overcoat thickness	6 [um]
Glaze thickness	200 [um]
Glaze radius of curvature	2 [mm]

Dot gap width

The dot gap indicates gap "G" between the heater and the heater shown in figure 2. When the gap width is narrow, temperature range in the direction of the heater row becomes small, and the temperature distribution of color development layer becomes more uniform. However, there is a limit on the manufacturing. Usually, overcoat layer is formed on the surface of heater therefore the temperature distribution on the head surface is made uniform on the heater surface. Moreover, considering the heat conduction from the surface of paper to color development layer, the gap need not be adjusted to 0. However, because suitable gap width is different according to the paper structure and the head overcoat structure, optimization is necessary.

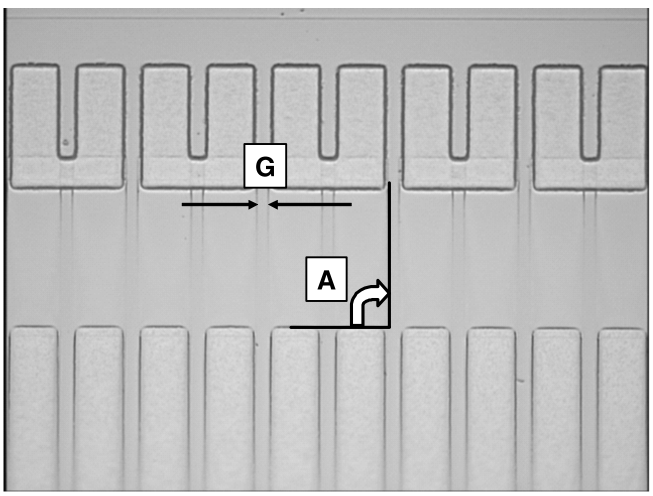

***Figure 2**. Dot gap width "G" and heater angle "A"*

Heater angle

The heater angle indicates angle "A" shown in figure 2. The heater queues up vertically in the direction of paper feed usually, therefore, when there is the low temperature part like the gap between heaters on the head, the low temperature part is always caused on the paper, and the printing density becomes not uniform. To this problem, it is possible to evade constant low temperature by angling the heater, so the temperature distribution is made uniform.

FEM analysis result

Figure 3 shows a temperature distribution on the surface of the heater and the surface of color development layer with 9 micrometer width of the gap. It can be confirmed that the heat generated by the heater diffuses in the head overcoat, and the influence of the gap width has become small in color development layer. Figure 4 shows the relation between the gap width and difference in temperature between heater and gap. We can calculate necessary gap width for homogenization of temperature distribution. This value changes depending on the thickness and material of the overcoat and depth of color development layer etc. Moreover, it changes depending on the printing speed and the energizing method of thermal head.

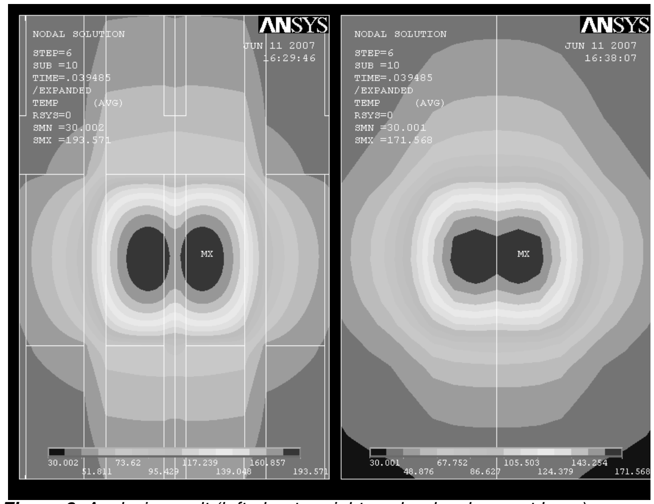

***Figure 3**. Analysis result (left : heater, right : color development layer)*

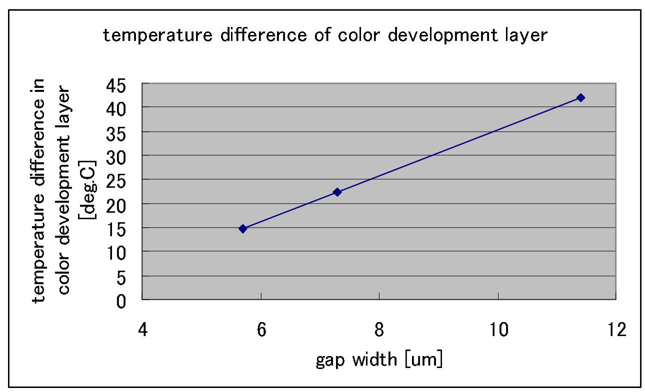

***Figure 4**. Relation between the gap width and the difference in temperature between heater and gap*

Figure 5 shows a temperature distribution on the surface of the heater and the surface of color development layer when heater is changed to 60 degrees. Figure 6 shows a temperature distribution on the head surface of simulation and actual measurement when heater is changed to 45 degrees. There is a difference in the thermal diffusivity to the electrode when both are compared. However, it is due to the emissivity difference of the head material, and distribution can be reproduced well. The temperature distribution of the gap neighborhood becomes flat as the angle becomes low as shown in the figure 7.

As mentioned above, we came to be able to calculate the temperature distribution of color development layer by the analysis that used three-dimensional model, so we became possible to know the influence that the head structure, the energizing control, and the print speed, etc. gave to the print result more in detail.

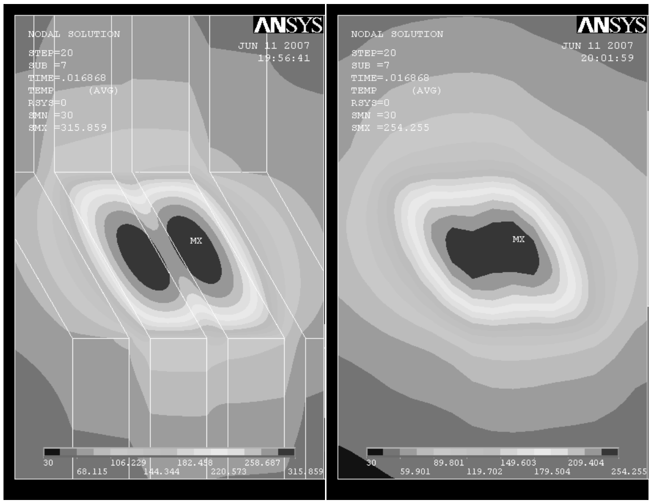

***Figure 5**. Analysis result of heater angle 60 degrees (left : heater, right : color development layer)*

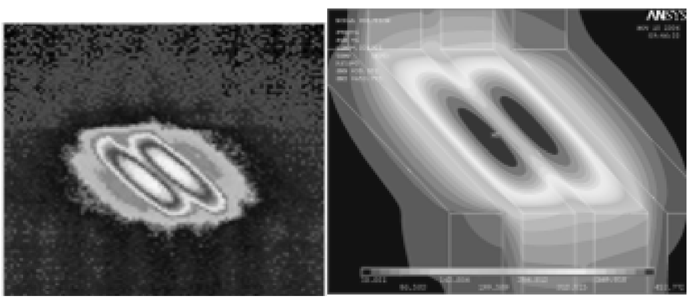

***Figure 6**. Temperature distribution of head surface (left : actual measurement, right : simulation)*

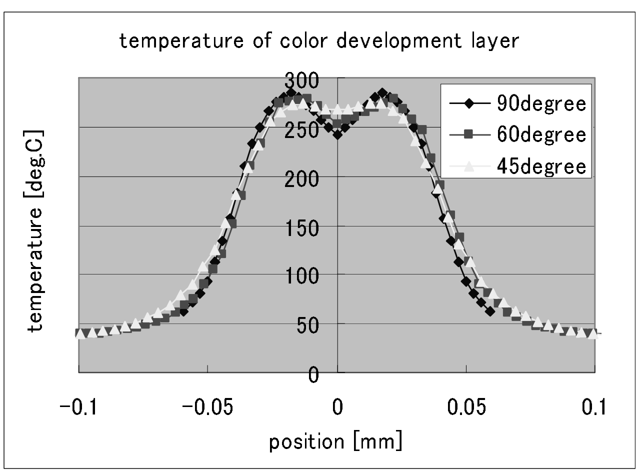

***Figure 7**. Relation between the heater angle and the difference in temperature between heater and gap (analysis result)*

Confirmatory experiment

We made the prototype of head that changed the gap width and the heater angle, and compared it with the analytical result. Figure 8 and 9 are results of measuring the density of the printing result with prototype heads.

When the width of the gap narrowed, we confirmed the density increased. Moreover, the density increased though the angle of the heater became low.

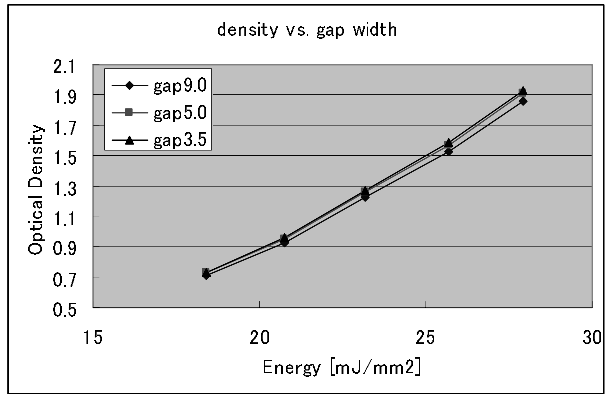

***Figure 8**. Density of the printing result with prototype heads (gap width)*

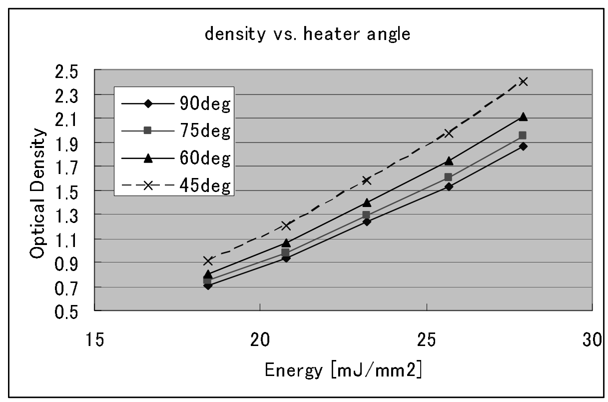

***Figure 9**. Density of the printing result with prototype heads (heater angle)*

Conclusion

We examined the head structure by three-dimensional analysis model of a thermal head and paper to make full-color thermal print high-quality.

1. Temperature distribution estimate of color development layer in the paper became possible by three-dimensional analysis model.

2. The relation between the head structure and the temperature of color development layer was clarified.

3. We made the prototype of head and confirmed the temperature distribution of color development layer in the simulation had a strong relation to the printing density.

References

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Author Biography

Hisashi Hoshino received his master of engineering degree in graduate school of Information Systems, the University of Electro-Communications in 1997. He has worked at Alps Electric Co., Ltd. System Devices Division since 1997 and is currently an engineer in the engineering department. He is designing an energizing control for thermal transfer printing and developing a thermal print head. He is interested in recreating the print process with simulation model.