Development of a thermal print head by 3D thermal analysis

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Abstract

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The photo printer of a dye-sublimation thermal printer is widely used for a consumer use and a business use as an output device of the digital camera image. On the other hand, a thermal printer is a simple structure, and it is small suitable. Therefore, it is widely used for a direct, thermal printer and a mobile printer of the built-in type. The power saving of a thermal head have to achieve for the battery longevity in a mobile printer and the speed-up of the dye sublimation photo printer.

The performance demanded from a thermal head differs respectively, and applies the technique of 3D analysis to the development of a thermal head for various pencil press of these thermal printers. In this paper, it reports on the result of review that 3D thermal analysis to the optimization of the design parameter of a power saving thermal head. And, it reports on the color printer that uses the developed power saving thermal head.

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 Zink.

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 examined the influence of the thickness of the protection layer of a thermal head and the influence of the electrode length. 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.

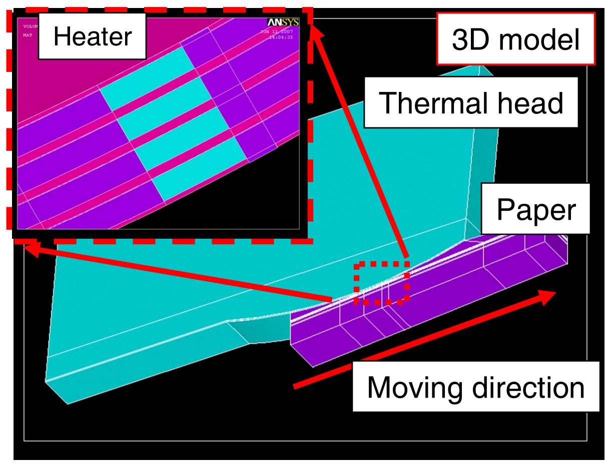

***Figure 1**. 3D analytical model*

$$\rho c\left(\frac{\partial T}{\partial t}+vx\frac{\partial T}{\partial x}+vz\frac{\partial T}{\partial y}+vz\frac{\partial T}{\partial z}\right)+\lambda\frac{\partial^2 T}{\partial x^2}+\lambda\frac{\partial^2 T}{\partial y^2}+\lambda\frac{\partial^2 T}{\partial z^2}=Q \qquad (1)$$

ρ: *Density*
c: *Specific Heat*
T: *Temperature*
t: *Time*
vx, vy, vz: *Velocity of a moving fluid*
λ: *Thermal conductivity*
Q: *Generation of heat*

We used ANSYS10.0, an FEM analytic software program, as the means for three-dimensional analysis. Assuming a model simulating relative motion of the head and paper, the analysis employed Mass Transport function of the software. Heat conduction equation of the model is given as in Equation 1. Table 1 shows material properties.

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

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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.

Table1 Material Property

Materials	Thermal conductivity [W/mK]	Specific heat [J/kgK]	Density [kg/m3]
Heat sink	218	900	2.69E+03
Adhesive	0.92	1300	2.00E+03
Alumina	25.1	960	3.50E+03
Glaze	0.75	780	2.20E+03
Heater	57	152	1.66E+04
Electrode	237	902	2.70E+03
Overcoat(Head)	3	1000	3.20E+03
Overcoat(Media)	0.34	2300	1.50E+03
Heat sensitive layer	0.2	1500	1.30E+03

Content of FEM analysis

We analyzed the relation of head structure and temperature distribution of color development layer by using this analytical model. Analysis result of the head thickness of over coat and the electrode length is shown. In each analysis, value of table 2 was used as a common condition.

Table 2 Head specification

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

FEM analysis result

We calculated the head structure and head generation of heat by three dimensional analyses. The appearance of the generation of heat distribution is understood from the analysis by three dimensions well. The relation between the head over coat layer thickness and the head surface temperature is shown in fig2. It is understood that the temperature of the heater rises by the film thickness of the coat layer thin.

As for this relation, the result of review and the correlation done in the past are seen. We understood it was a power saving to thin the thickness of the head over coat layer. However, when the head protection film is thin, reliability becomes a problem.

The relation between the electrode length and the generation of heat temperature is shown in fig3. The length of the electrode of

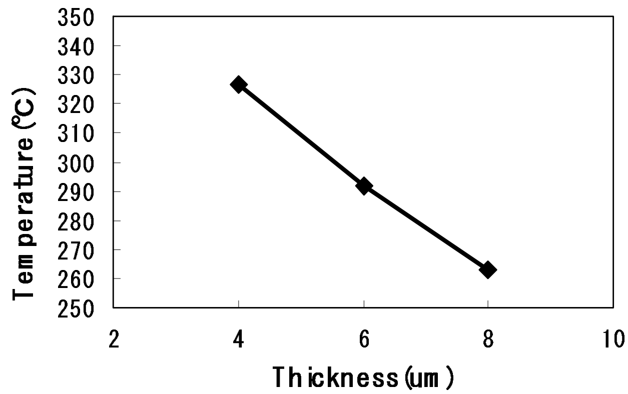

***Figure 2**. The relation between over-coat film thickness and temperature*

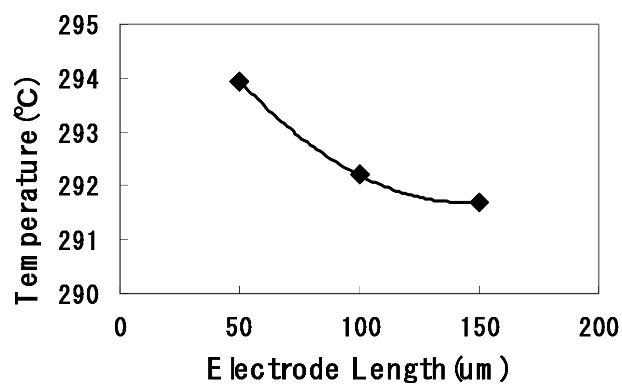

***Figure 3**. The relation between electrode length and temperature*

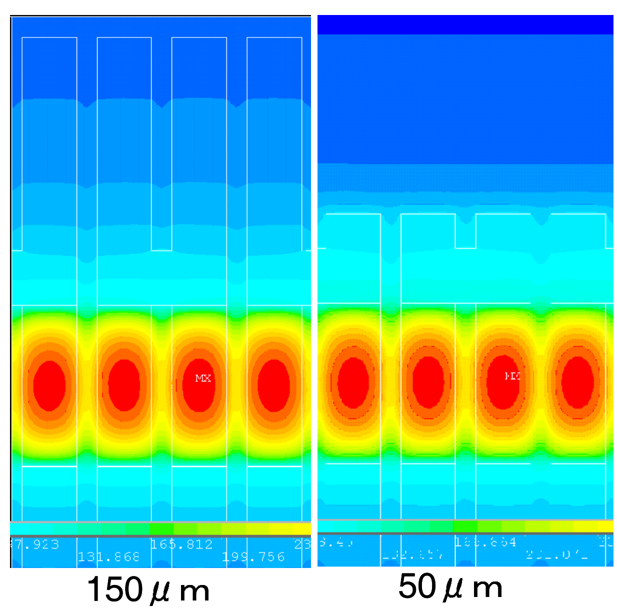

***Figure 4**. The relation between electrode length and temperature distribution*

the head in the turn structure of electrodes is shown with the electrode length. The tendency to which the generation of heat temperature lowers by the electrode length longer than this graph is understood. As for 100um or more, it is understood that the inclination of the decrease in the temperature becomes it from this graph. To confirm this cause, the heat distribution of three dimensional analyses was confirmed.

The result is shown to fig4. The electrode length shows the generation of heat distribution of the time of 150um and 50um in fig4. The appearance where the heat of the heat source diffuses in the direction of the electrode is understood from fig4 in the head with a long by return electrode. It is understood that heat has extended through the electrode material with a high thermal conductivity. The temperature gradient on the surface understands it is gradual in the direction of the turn electrode. Therefore, it is understood that fig3 made how of the temperature of 100um or more to fall gradual. The temperature of the electrode goes up when the electrode length is short.

It is thought that this is because heat doesn't diffuse easily to the surrounding because the electrode with a high thermal conductivity is short. Therefore, it is understood that it is set to the power saving of a thermal head short that the turn electrode length, and the structure that it doesn't let heat go in the electrode as much as possible is desirable.

fig5 shows the section profile of the generation of heat distribution. Y axis occupies the temperature ratio. The ratio of the temperatures in the surrounding when the peak temperature is assumed to be 100% is shown. As for the head that temperatures fluctuate in the position of the electrode is larger by return than fig5, and the electrode is shorter, The electrode understands and it is understood that the temperatures are 20% higher than long heads of a short head. Electrode length short, thermal head is a power saving. However, the dirt of the print occurs when the temperature on the electrode is high. Optimization that prints as the effect of the power saving is needed responding at the print speed. The relation between the electrode length and power consumption was examined.

The result is shown in fig6. Y axis of fig6 shows the electric power of the head of 300℃ in generation of heat temperature. It was changed that the electrode length, and examined the relation to power consumption for the electric power of the head.

Moreover, the length of the heat source was changed to 90um and 140um and the relation of power consumption was examined. It is understood that the shorter it is the electrode length, the lower power consumption is. Moreover, one with short heater length understands and the thing with a low electric power is understood. It is understood to become the shorter the relation between the length of the heater length and power consumption is the electrode length, the more remarkable. Because it is thought that it is because the ratio of the mass of the electrode to the area of the heater becomes small.

We made the head for trial purposes, and did the temperature survey. The result is shown in fig7. As a result, it is understood that it is an electric power difference of about 3.5% than the temperatures fluctuate where the head with a short electrode shows the result in which the generation of heat temperature is high. Because this is similar to the value that occupies it with fig6, it has been understood that 3D analysis was appropriate.

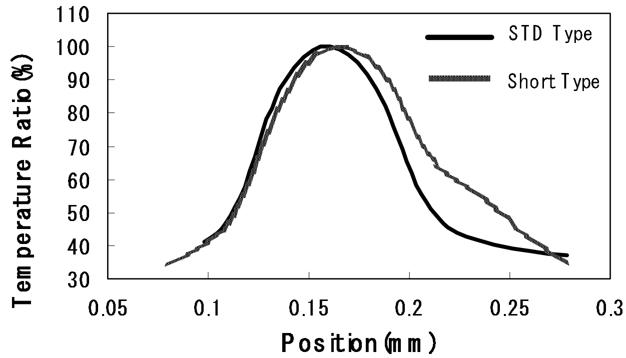

Figure 5*. The relation between electrode length and temperature profile*

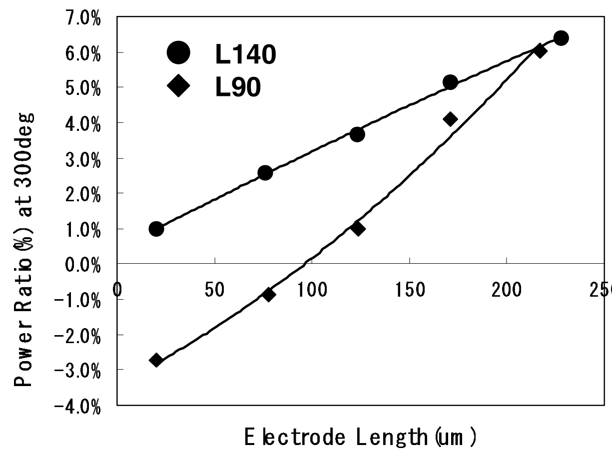

Figure 6*. The relation between electrode length and power ratio*

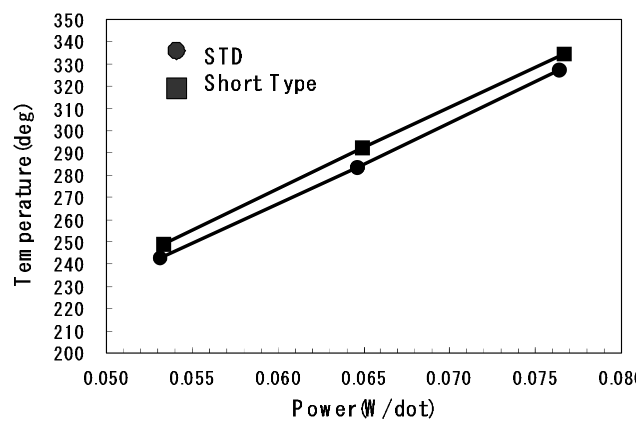

Figure 7*. Relation between power and generation of heat temperature by experiment result*

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 examined the influence of the thickness of the protection layer of a thermal head and the influence of the electrode length.

4. We can develop the head and confirmed the temperature distribution of color development layer in the simulation had a strong relation to the printing density.

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Author Biography

Hirotoshi Terao received his BS degree in materials engineering from Mining College at Akita University in1991 and .he received his Dr degree from Niigata University in 2006. He has worked at Alps Electric Co., Ltd. since 1991 and is currently a senior research scientist chief engineer in the R&D department. His interests are in research and development of thermal transfer technology and thermal print head. He received a technical award from The Society of the Electro photography of Japan in 1996.

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