Development of Low-power Thermal Printing Technology

Hisashi Hoshino and Hirotoshi Terao
ALPS ELECTRIC CO., LTD.
Iwaki, Fukushima, Japan

Abstract

We examined a power saving on thermal printing. We looked into thermal head structure, energizing condition and medium structure suitable for power saving. The numerical analysis by the finite element method was applied to the examination. In order to confirm the parameters influence, contribution rate of each parameter was examined by optimization tool based on experimental design. We have achieved power saving by this examination.

Introduction

With the spread of digital cameras, photographic printers for the digital image output are spreading rapidly these days. There are several methods for these photographic printers such as Digital silver halide, Inkjet and Thermal. We are studying Thermal printing method such as a direct thermal or dye sublimation suitable for mobile. A weak point of this method is that power consumption is higher than as of Inkjet. Battery drive is required for a mobile device therefore we have to reduce power consumption. So we examined power-saving. By carrying out FEM numerical analysis combined with an optimization support tool, we were able to optimize it efficiently regardless of many design parameters.

Method of Optimization

We found the optimum design parameters by FEM simulation. During the simulation, we planned promotion of efficiency by using optimization support tool OPTIMUS (NoesisSolutions). In addition, by using technical calculation software Mathcad (Mathsoft) at the same time, optimization using Taguchi Method which is the method considers robustness was completed almost automatically.

FEM Analysis

With ANSYS9.0, we performed analysis by a two-dimensional model. The analysis model as shown in Figure 1 modeled a head (a glaze, a substrate, a heat sink) and a part of the media (thermal paper) and Table 1 shows material properties. We use a mass transport function so that the media reproduces a relative phenomenon to move for a fixed head (expression (1)).

We calculated how the heat that occurred with heating element of a head conducted it in the color development layer of the media by this analysis. We evaluated it in the highest temperature of the media color development layer. Table 2 shows design parameters. In the Table 2, “R” means “radius of curvature” and “ ” means “thermal conductivity”. We found the results of the most suitable combination of these parameters. We evaluated it at temperature of tenth dot that a temperature change was stable to reduce analysis time per once.

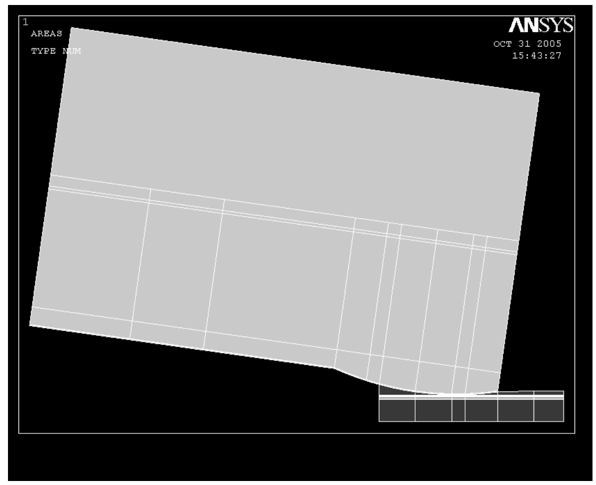

Figure 1. *FEM analysis model*

$$\rho c(\frac{\partial T}{\partial t}+vx\frac{\partial T}{\partial x}+vy\frac{\partial T}{\partial y})+k\frac{\partial^2 T}{\partial x^2}+k\frac{\partial^2 T}{\partial y^2}=Q \qquad (1)$$

ρ
c Specific
T Temperature
t
Vx , Vy Velocity of a fluid (mass
k Thermal conductivity
Q Generation of heat

Table 1: Materials 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

Table 2: Design parameters

Design parameter		1	2	3
Head	Glaze R [mm]	2	4	N/A
	Overcoat thickness [um]	4	6	8
	Electrode thickness [um]	0.5	1.0	1.5
	Heater length [um]	90	120	150
	Glaze thickness [um]	110	155	200
Media	Overcoat thickness [um]	0.5	1.0	1.5
	Substrate thickness [um]	50	100	150
	Substrate [W/mK]	0.10	0.15	0.20

Application of Optimization Tools

We used OPTIMUS which was automation and optimization support tool this time. OPTIMUS applies Design of Experiments (DOE) to get much information at less calculation number of times and creates a Response Surface Models (RSM) based on the result. Grasp of design space such as contribution ratio is enabled thereby. In addition, it possesses various optimization algorithms and can find the most suitable value automatically. On that occasion the most suitable value is found in a shorter time if I decide an initial value from RSM. The optimization that considered robustness by giving each design parameter variations is possible, but does not apply it this time. On the other hand, we carried out optimization in Taguchi Method which was the technique that considered robustness by applying Mathcad at the same time. In this case at first Mathcad performs a layout to orthogonal table automatically. The result is handed to OPTIMUS as input data, and it carries out a calculation of repetition. The output returns to Mathcad again, and a calculation of SN ratio and a plot of a figure of factor effect are carried out automatically. Because orthogonal table is used in Taguchi Method, there becomes very few calculation number of times.

As an advantage with these tools, most work can be automated. An analyst has only to appoint technique. Time for simple work, such as allotment of a variable in DOE and entry task, and possibility of a mistake are largely reduced thereby

Examination of Optimization

Our goal was to achieve power saving of a head by thermal efficiency optimization as a system of a thermal paper and a thermal head.

Specifically, since head temperature and input electric power are in linear relationship, we have done a work to find out optimized design parameters which makes the temperature of color development layer highest under a condition of constant electric power. We explain it in an optimization procedure in Taguchi Method.

Making of Input Data

We decide orthogonal table to use and perform a layout to orthogonal table on Mathcad and hand it to OPTIMUS as a table (input data) of DOE. We used L18 in this examination. I allocate a design parameter of table 2.

Repetition Calculation by ANSYS

Figure 2 is a screen of OPTIMUS which shows a flow of this calculation. The steps a) Automatically create ANSYS input file from design parameters based on input data above (shown in "A"), b) Analysis (shown in "B") and c) Output (shown in "C") were automatically run repeatedly.

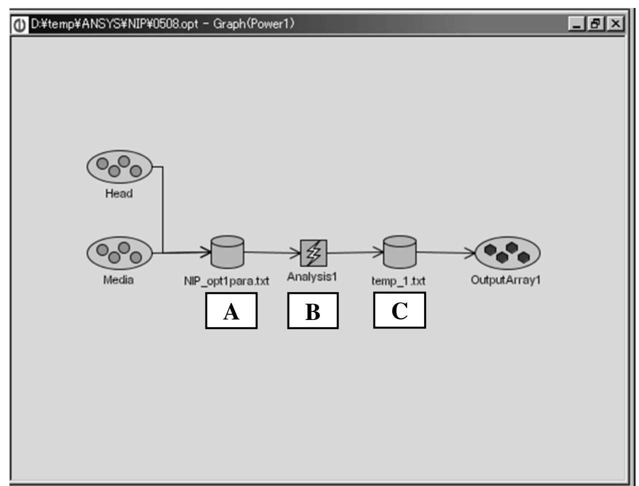

Figure 2. *OPTIMUS Sequence block diagram*

Making of an Approximation Model by RSM

Contribution ratio of each design parameter is found by creating a "Response Surface Models" from an analysis result by OPTIMUS. Figure 3 shows contribution ratio of each design parameter and we come to know size and a direction of contribution of each eight design parameters from this figure.

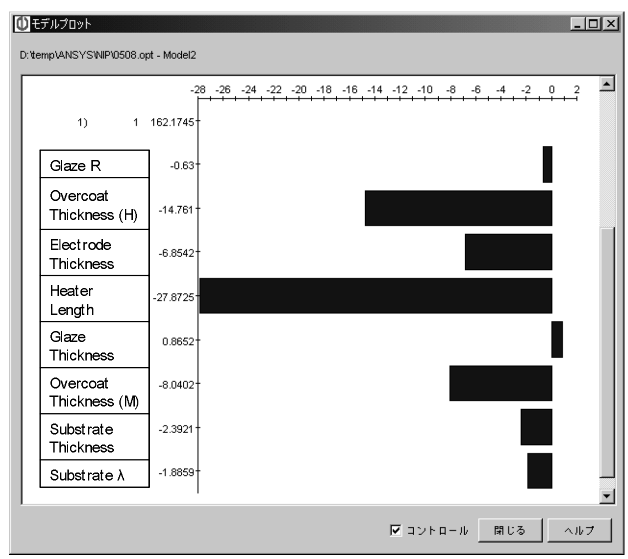

Figure 3. *Contribution ratio*

When bar is long, this figure shows that contribution ratio is high. From this result, we understood that contribution of heating element length and overcoat thickness of a head were particularly high. In addition, a sign of contribution ratio shows a direction of contribution. In this case, when the numerical value is small, as for the subtracted design variable, the output value grows big. This result showed that the output value grew big when we took a small value except the glaze thickness.

Processing of Output Result

A calculation of SN ratio and a figure of factor effect of Taguchi Method are performed automatically by returning an output result to Mathcad. Figure 4 is a figure of factor effect which demanded SN ratio is plotted. By this process, optimal solution was found like Table3. Because we did not really carry out a calculation by this combination, we confirmed the result by experiment which simulation reproduced the same result. For a current condition, about 26% temperature improved by making it this combination. Figure 5 is a change of color development layer temperature demanded in a current condition and optimum condition.

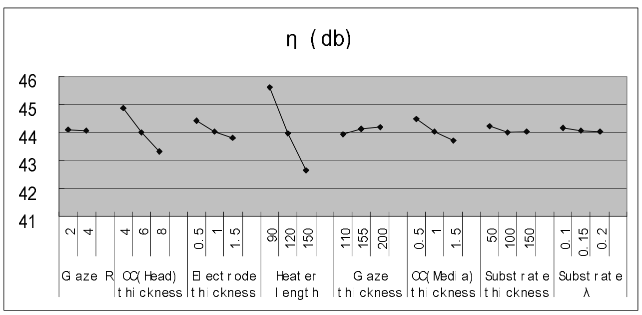

Figure 4. *Figure of factor effect*

Table3: Optimum combination

	Optimum		Current		
	level	SNR	level	SNR	
Glaze R	2	44.1	2	44.1	
Overcoat-H thickness	4	44.9	6	44.0	
Electrode thickness	0.5	44.4	1.0	44.0	
Heater length	90	45.6	90	45.6	
Glaze thickness	200	44.2	200	44.2	
Overcoat-M thickness	0.5	44.5	1.0	44.0	
Substrate thickness	50	44.2	100	44.0	
Substrate	0.1	44.2	0.15	44.1	**Gain**
SNR estimate		47.51		45.46	2.05
SNR verification		47.57		45.58	2.00

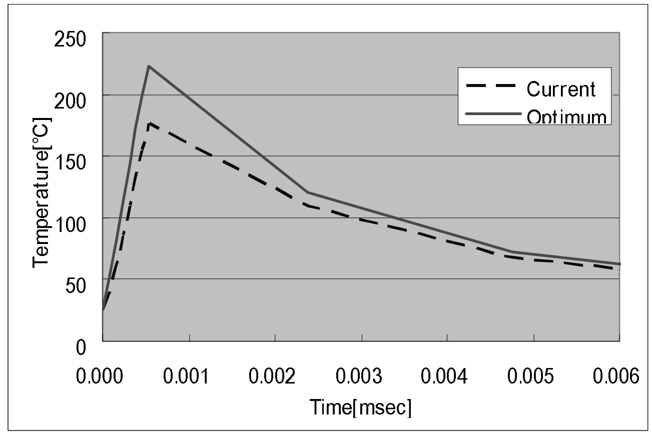

Figure 5. *Comparison of thermal response*

Confirmation by an Experiment

In a figure of contribution ratio provided by a process of optimization, contribution ratio of "Overcoat thickness (Head)" and "Heater length" was particularly high, so we really made a head about these and performed comparison with an analysis result. But because temperature of the color development layer in the media inside had difficulty with the measurement in the real thing, we compared it at head surface temperature. Figure 5 show relationship between overcoat thickness (Head) and head surface temperature. Figure 6 show relationship between heater length and head surface temperature. We confirmed that a value almost accorded with an experiment by analysis.

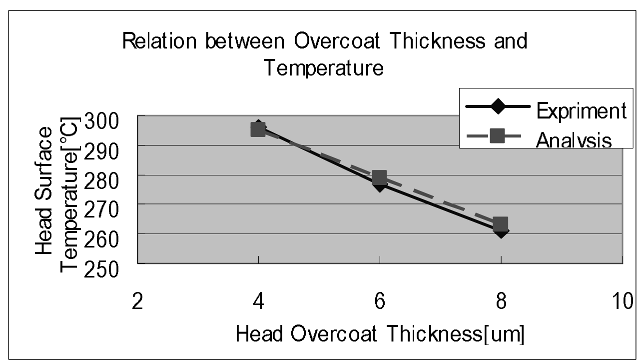

Figure 6. *Comparison of analysis with experiment (Overcoat thickness)*

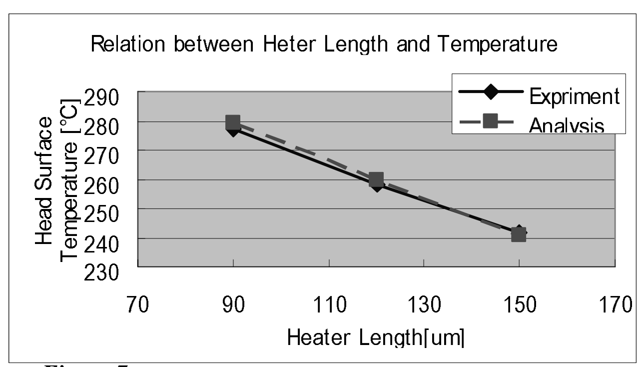

Figure 7. *Comparison of analysis with experiment (Heater length)*

Conclusion

We examined the power saving of thermal printing by using the FEM numerical analysis and the optimization support tool. We obtained the following conclusions by optimizing the head structure and the media structure.

1. We were able to save necessary power around 26% with less characteristic variation.

2. We confirmed the validity of the optimization method which consists of Optimization support tool and Taguchi Method support tool.

3. We were able to finish trial production and evaluation within a few days, which took several months in conventional way.

References

[1] H.Terao and N.Tsushima, T.Shirakawa, and I.Hibino, "Study of a Thin Film Thermal Print Head for High Definition Color Imaging Use", IS&T's NIP15:1999 International Conference on Digital Printing Technologies, p227 (1999).

[2] H.Terao, T.Nakatani, N.Tsushima, and I.Hibino, "Study of a Thermal Print Head for Multi-level Tone Printing", IS&T's NIP16:2000 International Conference on Digital Printing Technologies, p227 (2000).

[3] H.Terao, T.Nakatani, N.Tsushima, and I.Hibino, "Study of 1200dpi High Resolution Thermal Print Head", IS&T's NIP17:2001 International Conference on Digital Printing Technologies, p504 (2001).

[4] H.Terao and T.Nakatani, "Study of Thermal Print Head for High-Speed Print", IS&T's NIP19:2003 International Conference on Digital Printing Technologies (2003).

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.