Design of a Thermal Print Head by Contact Pressure Analysis

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Abstract

The printing method of the thermal transfer printer is to push an ink ribbon that is heated and melted by a thermal head to a printing paper, and transfer the ink to desired positions on the paper. Thus it is important to place the heater of the thermal head at the position where the contact pressure becomes most high. The visco elastic properties of the ink, PET and platen rubber were measured with a rheometer. The contact pressures on the thermal head were calculated by FEM. The contact pressures under consideration of visco elasticity were different from those calculated by elastic analysis. We designed the thermal print head by using this analytical result, and confirmed the print characteristic.

Introduction

This paper deals with contact problems between the thermal print head and the ink ribbon. The performance of the personal printer has recently been improved, and it is possible to obtain the high image quality equal to a photograph.[1] Figure 1 shows a schematic diagram of the thermal print head of the thermal transfer printer. The thermal print head presses the ink ribbon against the printing paper and simultaneously heats it. The melted ink is fixed to a desired position on the paper. There are two reasons to press the thermal print head. One is to transfer enough heat generated by the micro heater to the ink ribbon. The other is to crush the fiber of the paper and ensure the sufficient real contact area between the ink and paper. After the short cooling process the transferred ink is rubbed by the edge behind the micro heaters for the strong fixing of the ink. Therefore it is very important for the thermal transfer printer to clarify the contact pressure between the thermal print head and the ink ribbon. Elastic analysis[2,3] is not applicable to this contact problem since the ink ribbon is made of a plastic material, it exhibits the viscoelastic behavior. The ink on the ribbon is also viscoelastic material. Therefore viscoelastic analysis is essential to obtain the distribution of the contact pressure between the thermal print head and the ink ribbon.

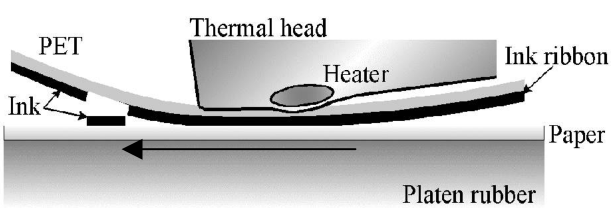

Figure 1. Details of thermal head and paper interface

In this paper the rheological properties of the ink and the platen rubber were measured using rheometers. The three elements Maxwell model was used to calculate the contact pressure. We examined the effects of the shapes and the moving speed of the thermal print head on the distribution of contact pressure. We designed the thermal print head by using this analytical result, and confirmed the print characteristic.

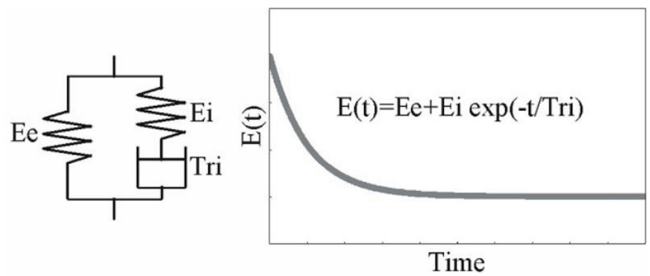

Figure 2. Maxwell Three element model

Measurement of Viscoelastic Properties

The viscoelastic properties necessary for a numerical simulation are two Young's moduli of the springs and relaxation time of the dashpot if the three elements Maxwell model shown in Fig. 2 is adopted.

Measurement of Viscoelastic Properties of the Ink

The viscoelastic properties were measured with two kinds of rheometers. One was Rhestress RS50 of Haake rheometer. The ink was molded into a disk of 35mm in diameter and 0.5 mm in thickness. The molded ink disk was sandwiched between two steel disks. Cyclic torsion was given to the upper steel disk with frequency sweep from 0.1Hz to 100 Hz. Table 1 demonstrates the obtained viscoelastic properties of the ink at each temperature. A trial calculation with the viscoelastic properties obtained at each temperature was carried out. However only the calculation in the case of 83 degrees centigrade was not possible since the ink was melted at that temperature and the Young's moduli were too low. We intended that the contact pressure be calculated at the temperature as near as possible to the melting point of the ink. Thus viscoelastic properties measured at 83 degrees centigrade were increased step by step up to the magnitude with which the calculation was possible. As a result the viscoelastic properties used in the calculation were 100 times larger than those measured at 83degrees centigrade. The relaxation time alone was not adjusted since it almost never depended on the temperature.

Table 1: Material Properties (INK)

	Ee (Mpa)	Ei (Mpa)	E (Mpa)	Tri (sec)
Liquid 83°C	0.782	0.076	0.868	0.00128
Liquid 83°C×100	79.2	7.6	86.8	0.00128
Solid 60°C	93	99	192	0.00125
Solid 25°C	380.8	370.8	751.6	0.00129

Table 2: Material Properties(Platen rubber,PET)

	Ee (Mpa)	Ei (Mpa)	E (Mpa)	Tri (sec)
Platen rubber	67.1	41.8	108.9	0.000158
PET	495	146	641	0.027

Measurement of Viscoelastic Properties of the PET Film and the Platen Rubber

The viscoelastic properties of the PET film and the platen rubber were measured using the rheometer RSA-II of Rheometric Scientific. The cyclic tension was given to the sheet type specimen with frequency sweep up to 100 Hz. In printing the PET film is pressed by the thermal print head at 200 degrees centigrade. Thus the viscoelastic properties of the PET film were measured at 150 degrees centigrade. The measurement for the platen rubber was carried out at 22 degrees centigrade. Table 2 demonstrates the obtained results.

Numerical Simulation

Boundary Conditions

Figure 3 shows the shape of the thermal print head measured by a profilometer, form talysurf S6. The locations of the micro heater and the edge are also shown schematically. The thermal print head was assumed a rigid body and moved in the right direction. The printing paper was not taken into consideration in this analysis since the structure of the paper was very complicated and it was difficult to construct a dynamic analytical model. Figure 4 demonstrates the FEM meshes. The thickness of the PET film and the ink were 3 micron and 2 micron. The platen rubber was 2.1 mm thick. The thermal print head was rotated in the counterclockwise by 3 degrees and attached to the printer as shown in Fig.4.First the thermal print head was pressed against the PET film with a force of 19.6(N) and sank a little bit into the platen rubber to bear the load. Then it was moved in the right direction at the speed of 50, 127, 256 or 508 mm/s. When the thermal print head started to slide over the ink ribbon, it rose slightly then finally reached the steady state. After that the distribution of the contact pressure acting on the head was unchanged. In this paper the contact pressure in the steady state was dealt with. The finite element method code of Marc Ver.7.3 was used.

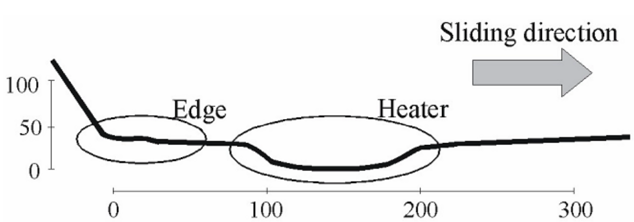

Figure 3. Shape of the thermal head

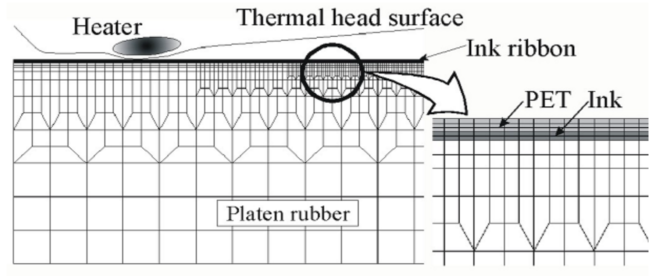

Figure 4. FEM analysis

Results of the Simulation

Figure 5 shows a displacement (a penetration into the platen rubber) and the contact pressure of the thermal print head at the moving speed of 254 mm/s. The simulated results by elastic analysis are also demonstrated. The left ordinate denotes the displacement and the right one the contact pressure. It can be seen that penetration of the head simulated by viscoelastic analysis is larger than that by elastic analysis. The contact pressure at the micro heater simulated by viscoelastic analysis showed a different behavior from that by elastic analysis. The peak of the contact pressure was on the right side of the micro heater in viscoelastic analysis. Therefore the optimum location for the micro heater should be there. The elastic analysis misleads the optimum location of the micro heater.

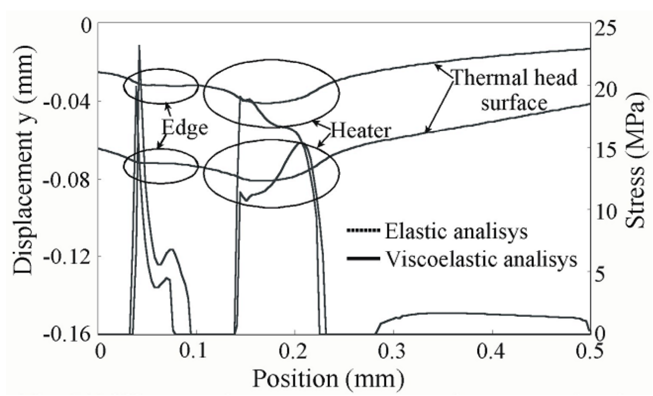

Figure 5. Difference in contact pressure between elastic analysis and viscoelastic analysis

Design of Thermal Print Head

Shape Simulation

By the viscoelastic simulation mentioned above, we have analyzed the head shape to obtain stable print characteristic regardless of the distance between heat element and the edge. Figure 6 shows two types of analytical results with different shape. It's Type A and Type B.

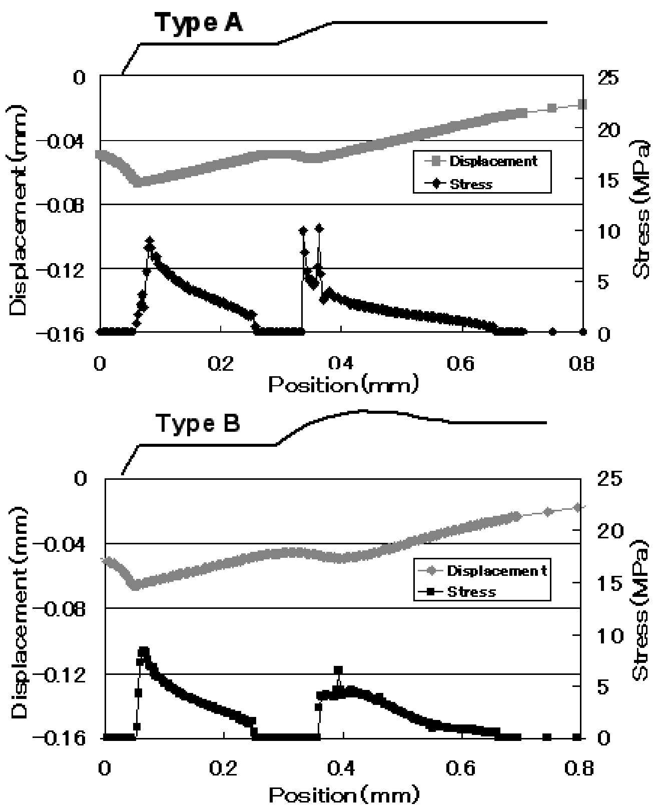

Figure 6.Difference in contact pressure between TypeA and TypeB

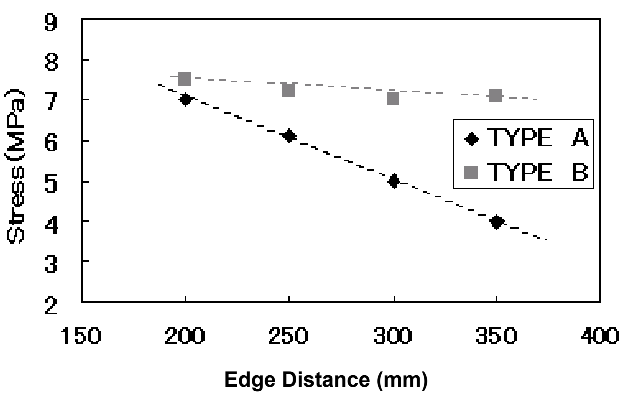

Figure 7. Relationship between edge distance and head surface stress

The surface stress with different edge distance was calculated for each thermal print head type. The result is shown in Figure 7. The Type A shows that when the edge distance increases the surface stress of the convex part (heat element) will decrease. On the other hand, Type B shows the constant surface stress regardless of the edge distance. This demonstrates that with a certain heat element shape, the constant surface stress could be kept regardless of the edge distance. Because the corner of heat is R-shape, a partial stress of decreases more than sharp shape. It is understood that the stress has been dispersed on average. In this way, we can expect more stable print with Type B, because the surface stress is less dependent on edge distance.

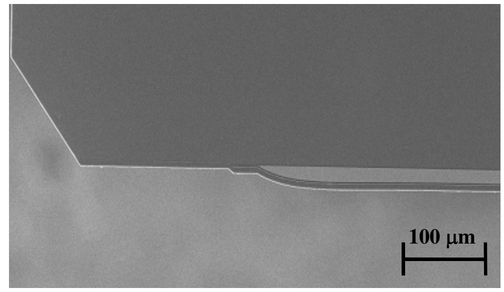

Figure 8. SEM image of cross section of the head

Characteristic Examination of Experimental Thermal Print Head

Based on the simulation result, Type B was chosen for the thermal print head shape. Figure 8 shows a sectional photograph of Type B. And, we verified the printing by using an experimental thermal print head. Figure 9 shows the relationship between the edge distance and the density. Duty 20% was measured. It shows the constant density within the edge distance range of 200 to 400 micro-meter. Finally, we were able to get the thermal print head that does not depend on edge distance by adjusting the edge distance to 300±50micro-meter.

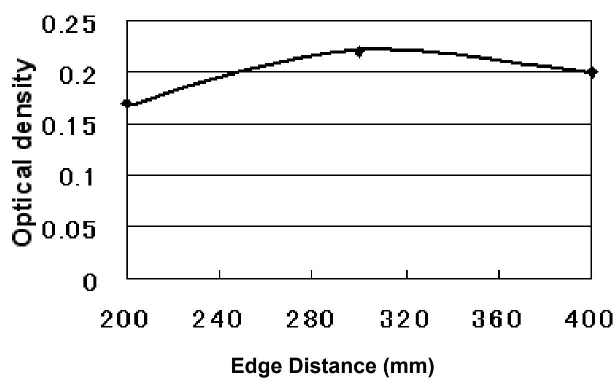

Figure 9. Relationship between edge distance and optical density

Afterward, we designed a high-resolution thermal print head of 600dpi and 1200dpi based on this analysis. To obtain the stable printing by these thermal heads, we did the simulation analysis of a head shape and did the verification. As a result, we were able to optimize the device model of the thermal head.

Development in the Future

We are developing a business printer by using the thermal print head designed by this examination.

Application to Card Printer and Security

This technology is optimum to the card printer if the ultra-high-resolution thermal head (600DPI & 1200DPI) will be used. Because a full-color graphics is achieved by 190lpi print by using 600dpi, and the micro character shown in Fig. 10 is printed in 1200dpi, it becomes an excellent on-demand card printer in security. Naturally, thermal transcript printer with pigment ink is good durability.

Conclusions

The viscoelastic analysis was essential to design the thermal print head. The viscoelastic analysis was carried out to obtain the distribution of the contact pressure between the thermal print head and the ink ribbon. The contact pressure was quite different from that calculated by the elastic analysis. Thus the viscoelastic analysis was essential to design the thermal head. The thermal print head of a steady characteristic was achieved by the contact analysis that considered viscoelastic.

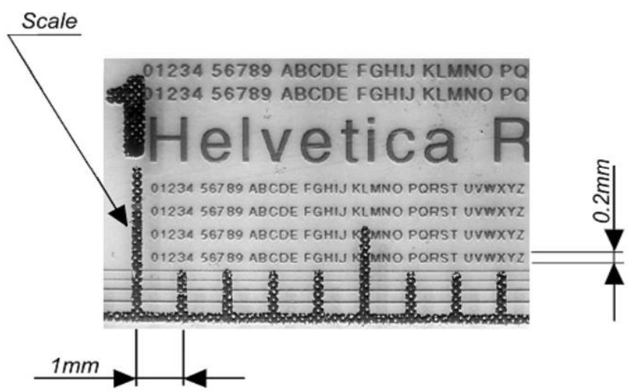

Figure 10. Micro character print

References

1. Hirotoshi, T., Toshifumi, N., Noboru, T. & Ikuo, H., Study of 1200 dpi high resolution thermal print head, IS&T's NIP17: 2001 International Conference on Digital Printing Technologies, pp.504-507, 2001
2. Isami, N., Hasegawa, T., Analysis of contact stiffness between metal ground surfaces using thin PET film, Computational Methods in contact mechanics IV, WIT Press, pp.49-58, 1999.
3. Isami, N., Akihiro, K., Kimio, K. & Satoshi, I., New joining method for laser scanner lenses by using a shrink fitter, Computational Methods in contact mechanics V, WIT Press, pp.31-40, 2001

Author Biographies

Hirotoshi Terao received his BS degree in materials engineering from Mining College at Akita University in 1991. He has worked at Alps Electric Co., Ltd. System Devices Division since 1991 and is currently a researcher 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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