Study of High Definition Thermal Transfer Ink Ribbon

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Abstract

Analysis was made of the thermal transfer printing process and 600-dpi high-definition thermal transfer ink ribbons. The results of analysis of this printing process revealed that four factors would play an important role in high-definition thermal transfer ink ribbons: (1) enough rupture strength of ink under printing pressure, (2) adhesive strength of ink and paper, (3) thinning of the ink layer and (4) adhesive strength between the heated part of ink and the basefilm. Using 2.5µm-thick PET film as the basefilm, a 600-dpi high-definition thermal transfer ink ribbon has been developed, with a 1.3µm-thick thermoplastic resin layer based on ethylene-vinyl acetate copolymer superimposed on a 0.9 µm-thick wax layer. The ink transfer properties of the ink ribbon were evaluated using a pendulum-type viscoelastic properties measuring instrument, with attention focused on the logarithmic decrement -temperature property.

Introduction

Thermal transfer printers are simple in mechanism and allow color printing using common paper. Nevertheless, they are used solely in word processing machines for text printing and in multicolor printers using extra-smooth paper, because they are allegedly designed only for surface-smooth paper and not adequate for gradation printing. Meanwhile, with the advancement of computers, there are growing needs for mechanically simple printers that permit high-quality full color printing.[1-7] We have been attempting to realize a high-quality full-color printer that is compatible with common paper and free from problems faced by thermal transfer printers.[8]

Focusing special attention to thermal ink ribbons, this report describes an ink-ribbon structure to meet ink transfer requirements and the feasibility of high-quality full-color printing using a thermal transfer printer. The most important factors in high-definition thermal transfer ink ribbons include the following:

(1) Enough rupture strength of ink under printing pressure.
(2) Adhesive strength of ink and paper.
(3) Thinning of the ink layer.
(4) Adhesive strength between the heated part of ink and the basefilm.

Conventional wax-based inks do not guarantee enough pressure-adhesive strength required for printing common paper, because ink viscosity substantially decreases during heating.[5-7] We found that, to print on xerographic paper, the conventional pressure-adhesive strength of 0.5kg/cm is not large enough and that instead a pressure of at least 2.0kg/cm is necessary. Then a study was conducted to discover a way to realize an ink that withstands the required pressure and allows high-definition thermal transfer printing. In addition, we evaluated the properties of ink ribbon by introducing a rarely used pendulum-type viscoelastic properties measuring instrument.

Evaluation of the Properties of Thermal Transfer Ink Ribbons

1. Evaluation Principle for Ink Ribbons

The most important properties of thermal transfer ink are ink strength, adhesive strength and temperature characteristics. Many measurements have been conducted for the viscoelasticity of thermal transfer ink itself, but there have been few such measurements on ink ribbons containing thin films of thermal transfer ink. We conducted measurement on the viscoelasticity of such ink ribbons with a pendulum-type viscoelastic properties measuring instrument, which are generally used to measure the viscoelasticity of paints. Pendulum-type viscoelastic properties measuring instruments serves their purpose by measuring damping oscillation, as shown below.

Figure 1 shows the mechanism of a pendulum-type viscoelastic properties measuring instrument located in relation to a measured object. If a measured object is set on the cylindrical fulcrum of the pendulum, the elasticity and viscosity of the pendulum is considered to influence the damping oscillation of the pendulum.

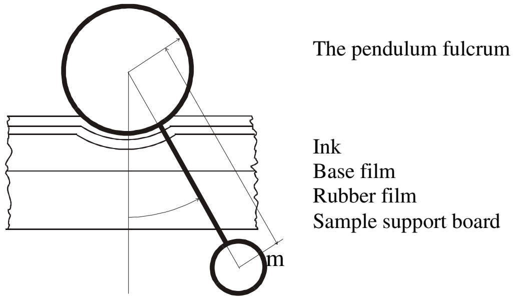

Figure 1. Principle model of pendulum-type viscoelastic properties measuring instrument

Pendulum movement is affected by viscous damping force, which changes in relation to the movement velocity of the measured object. If elasticity acts in proportion to displacement, the equation of motion around the cylindrical fulcrum is given as follows, at the angle θ of inclination from the perpendicular line:

Kinetic equation

$$ml^2 \frac{d^2\theta}{dt^2} + C_d \frac{d\theta}{dt} + (mg1\sin\theta + K_d\theta) = 0 \qquad (1)$$

When θ is small, sin θ can be replaced with θ, then,

$$\frac{d^2\theta}{dt^2} + \frac{C_d}{ml^2}\frac{d\theta}{dt} + \left(\frac{K_d}{ml^2} + \frac{g}{1}\right)\theta = 0 \qquad (2)$$

Here,

m; Pendulum mass
l; Pendulum length
g; Acceleration of gravity
K_d; Spring constant of measured object
C_d: Viscous damping coefficient of measured object
θ; Angle of inclination of pendulum

Therefore,

$$2\varepsilon = \frac{C_d}{ml^2},\ n^2 = \frac{K_d}{ml^2} + \frac{g}{1} \qquad (3)$$

Under above conditions,

$$\frac{d^2\theta}{dt^2} + 2\varepsilon\frac{d\theta}{dt} + n^2\theta = 0 \qquad (4)$$

Then, logarithmic decrement is given as follows:

$$\Delta = \frac{2\pi\varepsilon}{\sqrt{(n - \varepsilon^2)}} \qquad (5)$$

Oscillation cycle and Tan δ are shown as follows:

$$T = \frac{2\pi}{\sqrt{(n - \varepsilon^2)}} \qquad (6)$$

$$\tan\delta = \frac{\varepsilon}{\sqrt{(n - \varepsilon^2)}} \qquad (7)$$

Then,

$$C_d = 2ml^2\frac{\Delta}{T} \qquad (8)$$

$$K_d = ml^2\left(n^2 - \frac{g}{1}\right) \qquad (9)$$

Therefore, ε and n are given by Δ and T. And at

$$K_{d2} = K_d - K_{d1} \qquad (10)$$

$$C_{d2} = C_d - C_{d1} \qquad (11)$$

Then, K_{d1},C_{d1} are given by K_d - K_{d1}, C_d - C_{d1}.

Here,

K_{d1},C_{d1}; Spring constant, viscous damping coefficient of Rubber + basefilm
K_{d2},C_{d2}; Spring constant, viscous damping coefficient of ink
K_d,C_d; Spring constant, viscous damping coefficient of Rubber + basefilm + ink

2. Experiment

To analyze the behavior of ink used in high-definition thermal transfer ink ribbon at varying temperatures, measurement was made on the logarithmic decrement-temperature property of the ink ribbon by using pendulum-type viscoelastic properties measuring instrument. In the pendulum-type viscoelastic properties measuring system used in our experiment, the pendulum fulcrum is made of a 5-mm-diameter brass shaft.

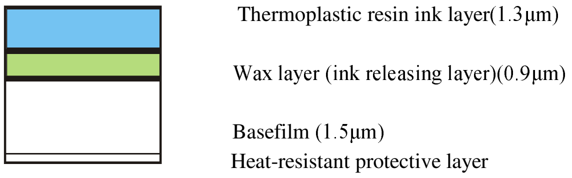

Figure 2. Vertical section of high-definition thermal transfer ink ribbon

Figure 2 shows the vertical section of high-definition thermal transfer ink ribbon developed by us. The ribbon consisted of a 0.9µm-thick wax-based ink releasing layer and a 1.3µm-thick EVA-based thermoplastic resin ink layer superimposed on a 2.5µm-thick PET (poly ethylene terephthalate) basefilm. On the back of the basefilm was a 0.25µm-thick heat-resistant protective layer. EVA denotes "Ethylene-vinyl Acetate Copolymer."

Figure 3 shows the logarithmic decrement-temperature property of high-definition thermal transfer ink ribbon placed on the sample support board, measured with pendulum-type viscoelastic properties measuring instrument. The sample support board was coated with 100µm-thick soft silicone rubber film. The temperature of the sample was measured with a thermocouple placed on the sample surface close to the fulcrum. The logarithmic decrement of soft silicone rubber film stayed around 0.03, almost constant over the temperature range. Silicone, whose surface is flat with few feeling of adhesiveness, showed a small logarithmic decrement value. The logarithmic decrement of PET film was 0.02, almost flat over the temperature range. PET film is harder than silicone rubber, which egnerate no feeling of adhesiveness.

The logarithmic decrement of high-definition thermal transfer ink ribbon indicate following

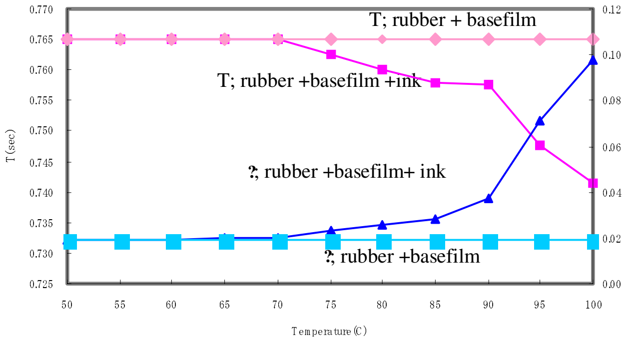

Figure 3. Logarithmic decrement-temperature property of high-definition thermal transfer ink ribbon

Δ; rubber+basefilm presents the logarithmic decrement-temperature property of the basefilm. **Δ;** rubber + basefilm + ink provides the logarithmic decrement-temperature property of the high-definition thermal transfer ink ribbon. The logarithmic decrement remained constant at about 0.02 at room temperature to 60°C. At 60 °C to 70 °C, the logarithmic decrement slightly increased. At 70 °C to 90 °C, the value increased 0.03 to 0.04. At 90 °C to 100 °C, the value jumped from 0.04 to 0.1.

Figure 4 illustrates the viscous damping coefficient and spring constant-temperature property of high-definition thermal transfer ink ribbon. These findings suggest the following:

The changes in this property corresponded to changes in viscosity η_1, η_2. Here, η_1**:** Viscosity coefficient of ink(cps)/1000, η_2**:** Viscosity coefficient of ink(cps)/1000000.

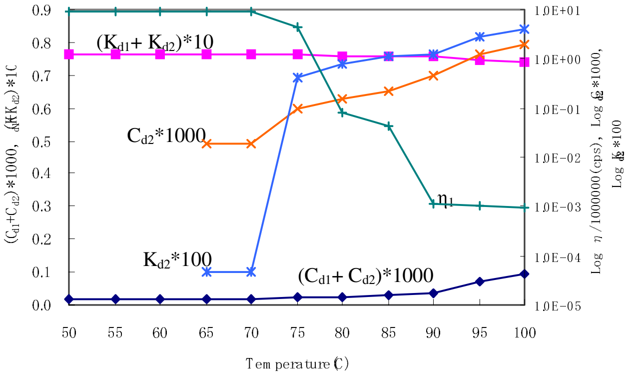

Figure 4. Viscous damping coefficient and spring constant-temperature property of high-definition thermal transfer ink ribbon

Therefore, at room temperature to 70 °C, both the thermoplastic resin ink layer and the wax-based ink releasing layer were solid. At 70 to 90 °C, the wax layer melted extensively. At 90 to 100 °C, there was interaction between the wax layer and the ink layer. Although viscosity of ink has fallen off along with a temperature rise, C_d and K_d are increasing.

These results of experiment indicate that the logarithmic decrement measured on pendulum-type visco-elastic properties measuring instrument does not reflect the viscoelastic of the ink material but the strength of the connection between ink and pendulum fulcrum are shown. Therefore, we can evaluate the strength of the cohesion power of ink by pendulum-type viscoelastic properties measuring instrument. At some point of logarithmic decrement, ink is considered to have effective adhesiveness.

Then, for high-definition thermal transfer ink ribbons, the logarithmic decrement-temperature property should ideally take a step form. Based on these results, we concluded that, by piling up the thermoplastic resin ink layer on the wax-based ink releasing layer, it would be possible to sharply increase the logarithmic decrement at low temperatures and maintain it at a high level in the high-temperature range.

To reduce ink thickness, it is required to enhance the viscosity of the main material of ink, thus strengthening pigment bonding. By using thermoplastic resin as the main material for the ink layer to withstand pressure, it may be possible to satisfy a requirement for thinning the layer. To achieve the printing density (OD value) of at least 1.5, the current pigment dispersion technology requires the ink thickness of 1.3 to 1.5µm, never 1µm or smaller. Expectations are high for the advancement of the technology.

Figure 5 provides a printing sample made by high-definition 600-dpi thermal printing. This sample offers sharp, clear characters, high-quality images and superior light resistance.

Figure 5. Printing sample

Conclusion

In this report, we have described our attempt to produce an ink ribbon using a thinned thermoplastic resin layer for high-definition printing. The thermal transfer ink was made mainly of thermoplastic resin to withstand high pressure-adhesive force. To reduce adhesive strength between the heated part of ink and the basefilm, a wax-based ink releasing layer was inserted between the basefilm and the ink layer, thus producing a two-layer ink ribbon.

To be more precise, the two-layer ribbon consisted of a 0.9µm-thick wax-based ink releasing layer and a 1.3µm-thick EVA resin-based ink layer, which were stacked on a 2.5µm-thick polyester basefilm. On the reverse side of the basefilm was formed an about 0.25µm-thick highly lubricous silicone-based layer. This structure realized a 600-dpi thermal transfer ink ribbon.

To evaluate ink used in ink ribbons, we can use as an indicator the logarithmic decrement as measured on a pendulum-type viscoelastic properties measuring instrument. The measurements of the logarithmic decrement revealed that the two-layer structure, which combined the thermoplastic resin layer with the wax-based ink releasing layer, markedly enhanced and accelerated the variation property of a single thermoplastic resin layer. The two-layer ink ribbon developed by us enabled the printing of sharp 600-dpi dots on highly smooth paper, as well as stable printing on copying paper.

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Biography

Ikuo Hibino graduated from Iwate University, Engineering Department, Electronic course in 1975. In 1977, completed Master course at the same and joined the same as assistant. In 1978, joined Alps Electric Co., Ltd. Since 1978, engaged in the development of equipment related to thermal printers. Received a Technical Award from the Electronic Photography Society.