Surface Heating Fuser with Roller Structure

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Abstract

The surface heating fuser structure has low energy consumption and high heating speed due to its low heat capacity and simple structure. The authors have introduced a surface heating fuser system in NIP 29. The heating material is composed of carbon nano tube and silicon rubber composite, and fabricated with thin film layer structure in order to minimize the heat capacity. A nip supporting member is applied to the heating tube inside slide along the surface of heating tube. But the high friction between the nip support member and the heating tube caused to the limitation of fusing speed and failure of electrical supply unit due to leaked lubricant. In this study, the roller type surface heating fuser structure is proposed. The fusing performance has been predicted by numerical simulation and verified by fabricated proto sample. The high fusing speed and durability of structure is confirmed through the evaluation of fusing system.

Introduction

In electro-photography process, the fussing process consumes the most of energy for its heating structure. The belt type fusing structure has been developed in order to reduce WUT (Warm up Time) and save energy for fixing a toner on a medium. [1-3] We have introduced the a new surface heating type fusing technology adopting CNT (Carbon Nano Tube)/LSR (liquid Silicone Rubber) composite for the heating material. [4] Due to the low heat conductivity and simple structure, the fast heating speed and high energy efficiency has been obtained. However the high driving torque for pressure roller should be applied because of friction force between the heating tube and the nip supporting member. In addition, a lubricant applied to the friction surface between the tube and nip member has been easily leaked to the both ends of the heating tube and it caused to the electrical hazards in electrical brush for fusser. .

In this work, we replaced the nip supporting member with sponge or silicon rubber roller. The driving torque has been substantially decreased and there has been no electrical hazard due to the absence of lubricant. In order to obtain high fusing performance, the numerical analysis for fuser structure was carried out and verified by the evaluation of the fusing device.

Fuser Structure

Figure.1 shows a fuser structure proposed in this study. The fuser consists of a heating roller and a pressure roller. The sponge roller is inserted into the heating tube composed of CNT (Carbon Nano Tube)/LSR(Liquid Silicone Rubber) composite. In case of the nip support fuser structure, the heating tube slide between the nip support member and the pressure roller under the force applied for nip pressure. It causes to severe shear stress to the heating tube and have the possibility of heating tube fracture. Compared to the nip supporting member structure, there is no sliding and friction on heating tube in proposed structure. In addition there is no lubricant on roller structure. The lubricant was poured into the surface between the heating tube and the nip support member in order to decrease the friction. The high temperature of heating tube decreases the viscosity of lubricant and it causes to the leakage to the both open ends of tube and electrical short between the electrode and the carbon brush for electrical supply unit. The heating tube with roller removes the listed problem and improved durability of the fuser.

But heat generated from the heating tube dissipates into the heating roller and it slow down the heating speed of the fuser. The nip width is also decreased at the same applied force between a heating roller and a pressure roller because stiffness of two roll structure is bigger than that of nip support member and pressure roller structure. In order to overcome the problems, the fuser structure has been optimized by numerical simulation.

Furthermore the heat generated at the paper non contact region is accumulated in the heating tube because there is no heat passage in longitudinal direction of the heating tube. Analysis for that phenomenon and some specific features for improving the heat accumulation at the paper non contact region has been adopted but not included in this study.

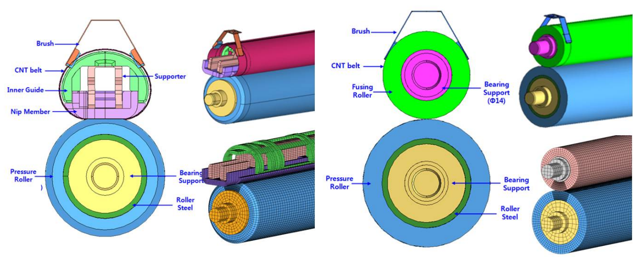

***Figure 1**. Nip Member Structure versus Roller Structure*

Figure 2 shows the concept of the CNT/LSR heating tube. Multi-wall CNT is applied for the heating material for its high conductivity and compounded with LSR material. Through extrusion process, a high electrical conductivity of the tube was obtained more than 500 S/m.

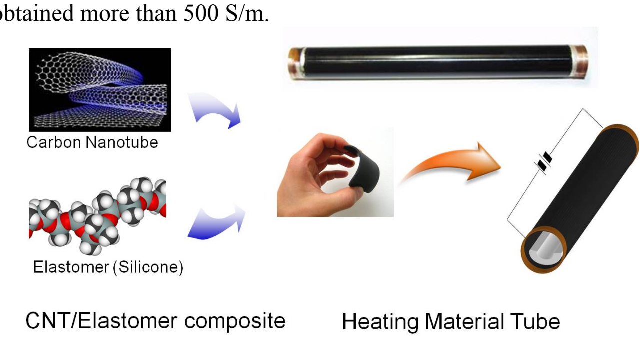

***Figure 2**. CNT/LSR Heating Tube*

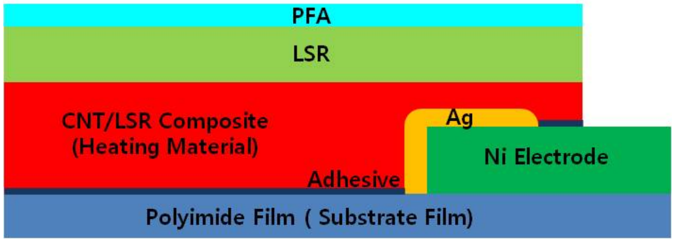

***Figure 3**. Cross Sectional View of Heating Tube*

The CNT/LSR heating material is flexible and can be fabricated to thin film tube having low heat capacity. Figure 3 shows the structure of the heating tube. Polyimide film is chosen as base layer of heating tube and the CNT/LSR heating material layer was extruded on the polyimide tube. LSR coated onto the CNT/LSR composite gives proper elasticity and thermal spreading, and PFA at the outmost layer is applied for easy release of a paper. A Nickel electrode conducting the electrical current to the heating material is integrated at the both side of the fusing tube. [4]

Numerical Simulation

In order to predict thermal conduction behavior of fuser device, Finite Elements Analysis was performed. Figure 4 shows the geometry of fuser structure. The heating roller consists of heating tube and sponge roller with hollow metal shaft and has diameter of 24mm. The pressure roller is composed of LSR and metal shaft and has diameter of 35 mm. Thicknesses of each layer of polyimide substrate, nickel electrode, CNT/LSR composite, LSR, PFA are 30um, 40um, 240um, 100um, 30um, respectively.

A target printing speed is 43PPM and a speed of paper at the fuser is 261.6mm/s. A fixing temperature is 180℃ at temperature sensor and a nip width is 9.5 mm. A paper was considered during the fixing process and a length of paper is 297 mm and a gap between the papers is 68 mm. The thickness of paper is 0.1 mm and the thickness of is 0.02 mm. The LSR layer between the PFA film and CNT/LSR heating layer is not adopted in this figure.

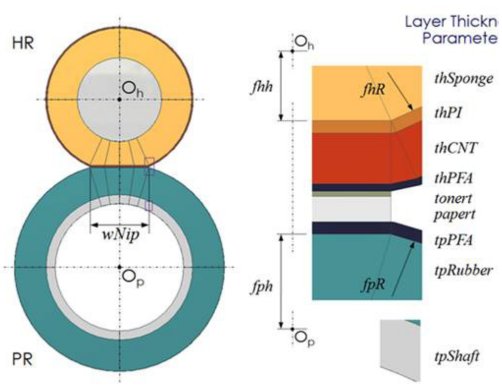

***Figure 4**. Geometry of Surface Heating Fuser Structure*

Thermal conduction is calculated from room temperature to the fixing temperature and toner fixing process for the paper is simulated by applying power duty modification for temperature control of fuser. The power duty is changed by the temperature difference between the current temperature of heating roller and target temperature of 180℃.

Figure 5 shows the result of temperature profile during heating and fusing process. WUT(Warm Up Time) is 3.97 seconds that means time period from room temperature to fixing temperature the calculation and heating speed is 21.3 ℃/sec. In case of nip member structure adopting the same heating tube, WUT is 3.4 seconds and faster than roller structure. The larger heat capacity of sponge roller than nip support member causes to late heating speed.

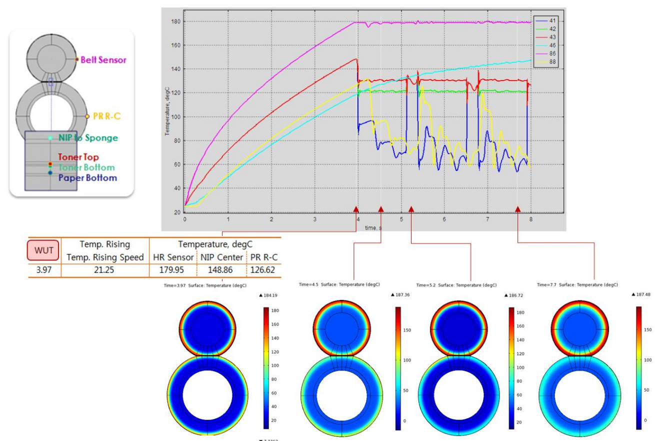

***Figure 5**. Temperature Profile during Heating and Fusing*

The sensor temperature at the front side of heating roller is 180℃ of the target fixing temperature and 148℃ in the surface of PFA film at NIP region. The heat generated from heating tube spreads into the sponge roller and the sponge and metal hollow shaft is so heated that heating speed becomes lower than the nip member structure. Since the heating roller has heated to the fixing temperature, the paper gets into the Nip and is heated to 142℃ at the top surface. The temperature of paper at the bottom goes around from 60℃ to 80℃. Figure 6 shows the temperature distribution of heating roller and pressure roller. When the paper gets into the NIP, Temperature drop at the Nip is observed due to the paper heat capacity.

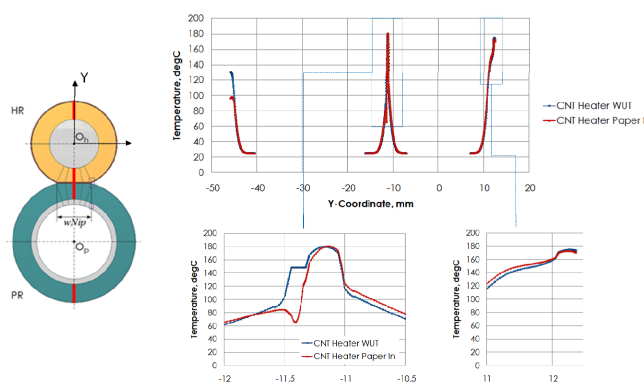

***Figure 6**. Temperature Distribution of heating roller and pressure roller*

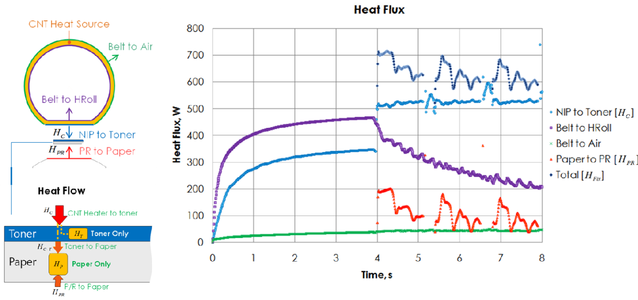

***Figure 7**. Heat Energy during Fusing Process*

The heating energy for fixing toner to paper is estimated by calculating heat flux for fixing process. Figure 7 shows the heat flux profile during fusing process. The Symbol of H_C is the heat flux from heating tube to the toner layer and H_T is heat flux of toner only , H_{C-T} is from toner to paper, H_P is paper only, H_{PR} is from pressure roller to paper, respectively. The relation of each heat flux is defined at Equation (1), (2). The total heating energy during fixing process is obtained by Equation (3).

$$H_T = H_C - H_{C-T}, \qquad H_P = H_C - H_{C-T} \tag{1}$$

$$H_T + H_P = H_C + H_{PR}, \qquad H_{fix} = H_C + H_{PR} \tag{2}$$

$$E_{Page} = \int_{page} H_{Fix} dt \tag{3}$$

TEC (Typical Energy Consumption) is calculated by summing up each print job due to the definition of TEC. The heating energy of print job #1 is calculated by above equations and heating energy of Job #2, Job #3, and Job #4 is assumed to be 90 % of print job #1. Final energy and sleep energy is assumed to be zero. As a result of calculation for TEC of the fuser, TEC is predicted to be 1810 Wh. In order to verify the calculation, A fuser unit is fabricated and TEC is measured for 1590 Wh. It is assumed that the difference between the simulation and the measurement results from temperature control simulation. The power duty ratio is modified due to temperature difference between the current temperature and the target fixing temperature. The deference is segmented to the period that have range of 3℃ but the temperature control of the fabricated fuser is more accurately controlled than the simulation.

Fusing Performance

Due to the low heat capacity of heating tube, temperature of the tube is easily affected by ambient situation and so it is a technical challenge to control and maintain the temperature of fusing system. The AC applied voltage has been controlled to maintain the target temperature. [5] In this study, a duty control of driving voltage has been applied to prevent the temperature overshoot in warming up the fuser and to minimize the fluctuation of temperature in whole heating element. The suggested surface heating fuser transfers heat directly from the heating tube to the paper. However fixedness could be unstable due to the low heat capacity and non uniformity of heating tube. In addition, the heating and cooling speed is so fast and the response of temperature sensor is so late that temperature control is a major hurdle for fusing performance. Thermistor is applied to the temperature sensor. The low cost thermistor has a time response more than 2 seconds. The measured temperature by thermistor shows the accurate results for target temperature. On the other hand the measured temperature by IR camera shows the temperature ripple in warming up process because IR Camera has more fast time response than thermistor. [4] Figure 8 shows the temperature profile during fusing process by IR Camera.

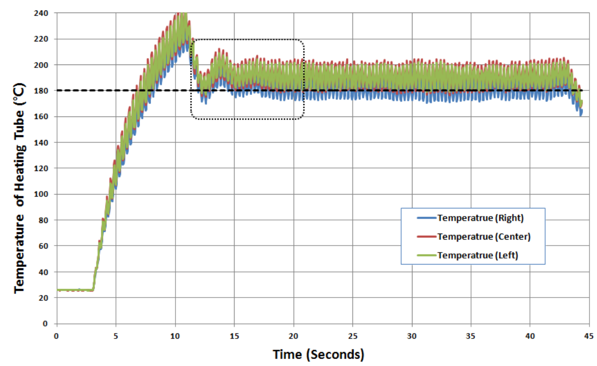

***Figure 8** Temperature Profile during fusing by IR Camera*

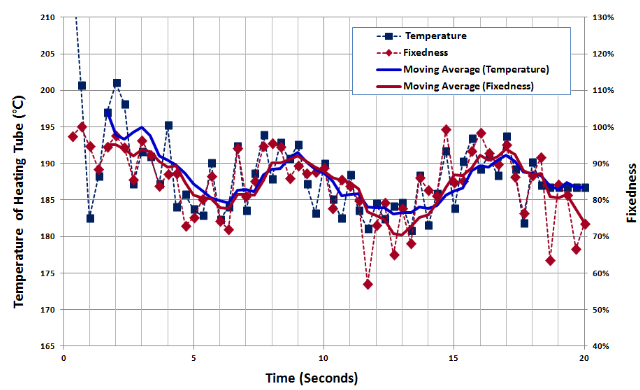

***Figure 9** Temperature and Fixedness during Fixing Process*

The temperature profile of heating tube shows a fluctuation due to variation of thickness and electrical conductivity of the tube and shows the temperature ripple in warming up process and the maximum temperature of the tube rises up to 240°C. The slow response of thermistor results to the ripple and the temperature profile measured by temistor does not show fluctuation and ripple. The fixedness in surface heating fuser is sensitive to the temperature of heating tube and temperature should be maintain more than fixing temperature. Average temperature during fixing process is higher than the fixing temperature because of fluctuation. Figure 9 shows the relation between the temperature of heating tube and the fixedness during fusing process. The time period of temperature in Figure 9 is marked in Figure 8. The moving average curve of the temperature is exactly coincident with the fixedness. The temperature fluctuation causes to high fixing temperature to accomplish the fixedness and the high fixing temperature increases the risk to the durability of fuser. In order to decrease the temperature fluctuation, the uniformity of heating tube should be accomplished by satisfying the requirement for thickness and electrical uniformity in heating tube manufacturing process.

Fabrication and Verification

The surface heating fusing device with roller structure was fabricated and evaluated. The device was integrated with fuser unit for A4 43 ppm monochrome laser beam printer. The two roller structure is hard to get nip with more than 10 mm for Φ24 and Φ 35 rollers compared to the nip support member structure. The 9.5mm nip width is obtained and the fixedness is accomplished for the 180℃ fixing temperature.

Ag Alloy wire brush and copper bush are applied for the electrical supply unit for fusing device as shown in Figure 10. In case of carbon brush applied for nip support structure, copper in carbon brush was oxidized at fixing temperature and bonding with carbon was weakened and carbon breaks into particles and forms a carbon film on the contact surface of electrode. The heat from heating tube is insulated by clip cover and contact area is minimized by applying copper clip.

The fuser unit is tested for durability and electrical safety. Electrical hazards by lubricant leakage and heating tube fracture by high shear stress in nip support member is improved.

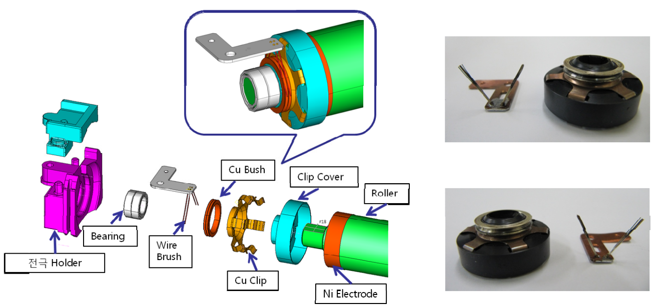

Figure 10 *Electrical Supply Unit by Wire Brush and Copper Bush*

Conclusion

The surface heating fuser with roller structure was proposed and developed. The durability and electrical stability were improved. The fusing performance and temperature control were investigated. The numerical analysis for fuser structure considering paper and temperature control was carried out in order to optimize the fuser system design. The fuser device was fabricated and evaluated in an A4 laser printer. The printing speed of the proposed fuser is more than 43 ppm. The WUT is 4.5 seconds and TEC is 1590Wh.

References

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Author Biography

Oh Hyun Baek received the B.S. and M.S. degrees in mechanical engineering from Korea University, Seoul, Korea, in 1991 and 1993,, respectively. He joined Samsung Electronics Co, Ltd. Suwon Korea, and he worked on research and study of ink jet and Laser Beam printing process at the Digital Media Communication R&D Center. His recent research topic is focused on fusing Device and 3D Printing process.