Development of Dual Heater Technology for On Demand Fixing System

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Abstract

Canon has developed a dual heater technology for controlling the temperature rise at non-paper regions for the on-demand fixing (ODF) system and has applied the technology to numerous laser-beam printer models. For the fuser heater, this technology uses a dual heater with two types of heating elements that differ in their lengthwise heat distribution. Further, the power applied to each of the two types of heating elements is varied according to the width of the paper to be printed on in order to control the heater's lengthwise heat distribution and thereby suppress the temperature rise at non-paper regions. In this study, the effect of the dual heater technology in suppressing the temperature rise at non-paper regions was estimated through comparison with the conventional ODF heater by using three dimensional heat transfer simulation. The temperature rise at non-paper regions in a prototype dual heater was found to be a close match to the estimation obtained through simulation, showing that the prototype operated as expected.

Introduction

Recent years have seen intense development of low heat-capacity fusers in order to reduce the power consumption of laser printers. Canon has developed the on-demand fixing (ODF) system and has applied the technology to numerous laser-beam printer models. The main technological issue with the ODF system is the suppression of the temperature rise at non-paper regions, which consists of fixing components and pressure components. The temperature rise at non-paper regions in fusers is one of the factors that limit the print speed for narrow sheets. Suppressing this temperature rise would allow higher print speed for narrow sheets.

Canon has developed a dual heater technology for controlling the temperature rise at non-paper regions for the ODF system. For the fuser heater, this technology uses a dual heater with two types of heating elements that differ in their lengthwise heat distribution [1]. Further, the power applied to each of the two types of heating elements is varied according to the width of the paper to be printed on in order to control the heater's lengthwise heat distribution and thereby suppress the temperature rise at non-paper regions. This technology is employed in the LBP8730i, which was released in November 2013.

In this study, the effect of the dual heater technology in suppressing the temperature rise at non-paper regions was estimated through comparison with the conventional ODF heater by using three dimensional heat transfer simulation. Additionally, the performance of the prototype dual heater was verified through comparison with the simulation results.

Product Overview

A product overview of the LBP8730i is provided below. The external view of the LBP8730i is shown in Fig. 1. The LBP8730i is a high-end A3 monochrome laser printer that provides high speed, support for numerous types of paper, environmental benefits, and higher-grade image quality. The main technical features of the printer engine include 40 page/minute high-speed simplex and duplex printing, quick wakeup based on the ODF system, power saving design featuring 0.9 W minimum power consumption and 2.1 kWh TEC value, and high-volume paper feeding supporting up to 5 way trays and 2000 sheets.

Figure 1. LBP8730i

Dual Heater Technology

An overview of the dual heater technology used in ODF system fusers is provided below.

ODF System Fuser

The structure of ODF system fusers is explained below. A cross-sectional schematic drawing of an ODF system fuser is shown in Fig. 2. In this fuser, a fixing nip is formed using a fixing film and pressure roller. The ceramic heater placed inside the fixing film is forced against the pressure roller by a pressure mechanism (not shown) through the film guide and stay. The sheet of paper inserted in the fixing nip receives heat from the heater through the fixing film and is pressed and fed by the pressure roller.

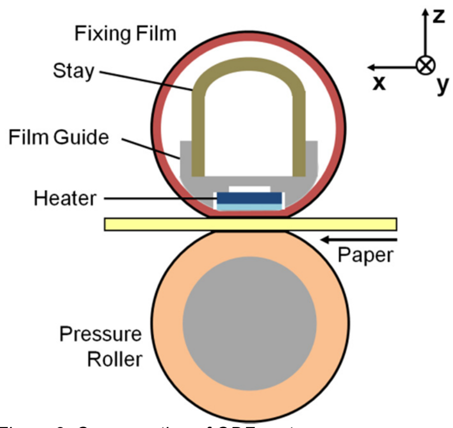

Figure 2. Cross-section of ODF system

Dual Heater

The schematic drawing of a conventional heater is shown in Fig. 3(a). When power is supplied from electrodes to a heating element that is printed on an alumina plate, a uniform lengthwise temperature distribution is formed within the maximum paper-width region.

A schematic drawing of a dual heater is shown in Fig. 3(b). The dual heater is equipped with two types of heating elements that have different lengthwise temperature distributions. Each heating element is powered independently. Heating element A, which is one of the two types of heating elements in the dual heater, is shaped so that the width of the heating element diminishes from the center to the ends in the lengthwise direction, making the resistance per unit length at the ends larger. Heating element A is positioned at the center in the heater's paper feed direction. Heating element B, the other type, is shaped so that the width of the heating element increases from the center to the ends in the lengthwise direction, making the resistance per unit length at the ends smaller. Heating element B consists of heating element B1, which is positioned at the upstream end in the paper feed direction, and heating element B2, which is positioned at the downstream end, connected in parallel. This design was devised to increase the heat supply efficiency by making the heat distribution in the paper feed direction uniform. Further, separate electrodes, A, B, and C, are provided to supply power to each heating element.

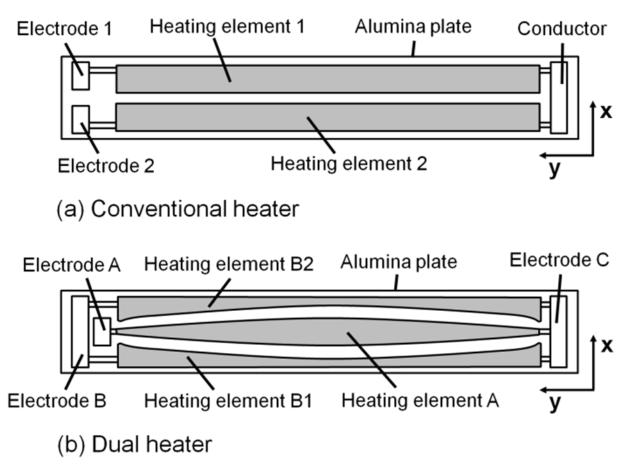

Figure 3. Configuration of heaters

Conceptual diagrams of lengthwise temperature distribution are shown in Fig. 4 for the heating elements of (a) conventional heaters and (b) dual heaters. When heating element A of the dual heater is heated, the temperature is set high at the ends. When heating element B is heated (B1 and B2 at the same time), the temperature is set high at the center. When heating elements A and B are heated at the same time, the temperature distribution is set approximately uniform over the maximum paper-width region.

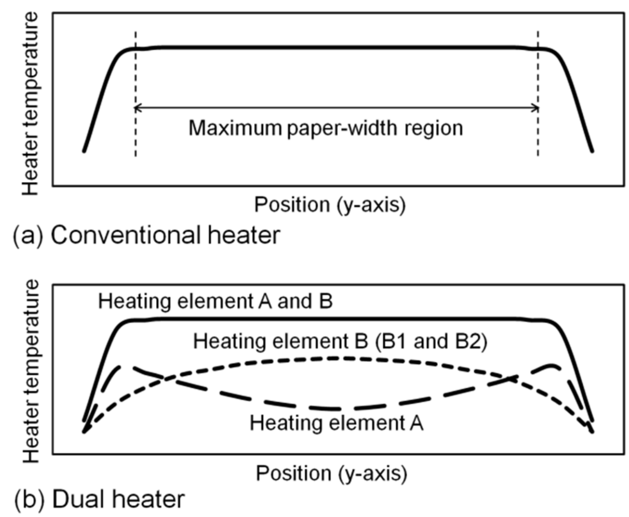

Figure 4. Temperature distribution for heaters

Temperature Rise at Non-paper Regions

Below the effect of the dual heater technology in suppressing the temperature rise at non-paper regions is estimated through comparison with the conventional heater by using three dimensional heat transfer simulation.

Conventional Heater

First, the temperature rise at non-paper regions was verified for the conventional heater (uniform lengthwise temperature distribution within the maximum paper-width region) of an ODF system fuser. The temperatures of the fixing film and pressure roller after continuously feeding 10 sheets of paper through a fuser capable of handling a maximum paper width of 304 mm were measured using thermography from the delivery end. The results are shown in Fig. 5. Figure 5(a) shows the results for feeding A4 sheets long edge (297 mm paper width, hereafter referred to as A4LE), and Fig. 5(b) shows the results for feeding A4 sheets short edge (210 mm paper width, hereafter referred to as A4SE). It can be seen that the narrower the paper width in comparison with the length of the heater's heating element, the greater the temperature difference between the paper region and non-paper region on the fixing film and pressure roller.

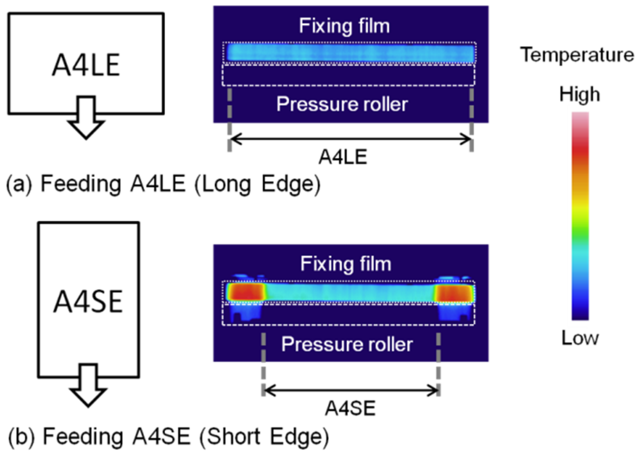

Figure 5. Temperature rise at non-paper regions

Simulation

Next, the effect of the dual heater technology in suppressing the temperature rise at non-paper regions is estimated through heat transfer simulation of the fuser.

In the simulation, consideration was given to heat transfer inside the parts based on Fourier's law, as well as heat transfer to the air based on Newton's law. The contact thermal resistance for heat transfer between parts was also considered [2].

In this simulation, a fuser through which paper is fed at the guide center in the paper width direction was assumed, and the simulation modeled halfway from the center of the feeding position. The composition details of the fixing film, heater, and pressure roller used in the heat transfer simulation are listed in Table 1. For the model calculations, 24 mm was used for the outer diameter of the fixing film, 30 mm for the outer diameter of the pressure roller, and 10.7 mm for the width in the feeding direction for the heater. The model included also a temperature sensor halfway across the length of the heater on the back side.

Table 1. Constitution of components

	Layer	Material	Thickness
Fixing Film	Top	PFA	12 μm
	Base	PI	64 μm
Heater	Top	Glass	65 μm
	Base	Al_2O_3	1 mm
Pressure Roller	Top	PFA	50 μm
	Elastic	Silicone Rubber	4 mm
	Core	Aluminum	Diameter 22 mm

Further, thermal conductivity λ [W/mK], specific heat Cp [J/kgK], density ρ [kg/m^3], and initial temperature were applied to each component, and input power IE [W] was applied to the heater. Contact thermal resistance H [mm^{2}K/W] based on actual measurements was applied between each of the components, and heat loss coefficient R [W/mm^{2}K] was applied to heat radiation from the component surface.

The effect of the dual heater in suppressing the temperature rise at non-paper regions is estimated through comparison with the conventional heater shown in Fig. 4.

The evaluation method of the temperature rise at non-paper regions using heat transfer simulation is described below. Power was input to the heater in a state where the fixing film and pressure roller were rotating at the speed of 186.4 mm/s. Paper feeding was started three seconds after power was input. The power input to the heater board was controlled so that the temperature detected by the attached temperature sensor reached 190 °C. The paper model was based on Red Label Superior FSC 80g/m^2 from Océ. An interval of 65 mm (0.35 s) was set between each sheet, and 10 sheets were continuously fed. Then, the temperatures of the fixing film and pressure roller were read.

The simulation results for the temperature rise at non-paper regions are shown in Fig. 6. The results are shown for the cases when the power supply ratio W_A [%] to heating element A of the dual heater was changed between 100%, 50%, 10%, and 0% of the maximum power supply. In these cases, the same power supplies to heating conductor B. For W_A=100%, the calculation is for applying the same lengthwise temperature distribution as the conventional heater.

In addition, Fig. 7(a) shows the lengthwise temperature distribution of the fixing film at the downstream end of the fixing nip after feeding 10 sheets, and Fig. 7(b) shows the enlarged view of one of the edges of the A4SE paper region.

As shown in Fig. 6 and Fig. 7(a), as W_A is decreased, the temperature of the fixing film after feeding 10 sheets decreases, suppressing the temperature rise at non-paper regions. On the other hand, as shown in Fig. 7(b), when W_A is 10% or less, the fixing film temperature at the edge of the A4SE paper region is low, which raises concerns about fixing defects in this area.

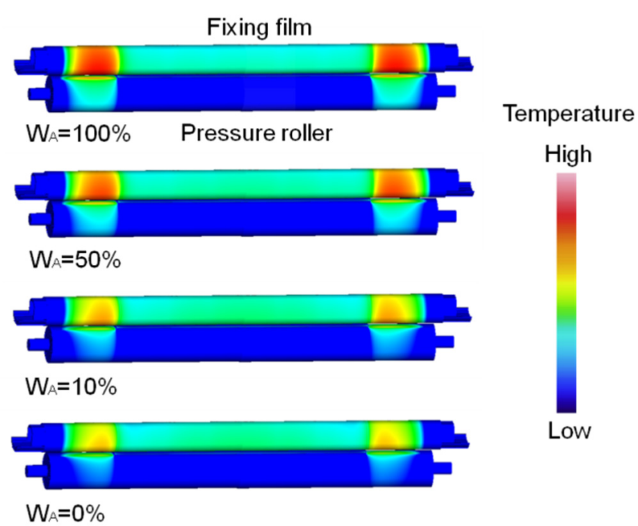

Figure 6. Results of simulations

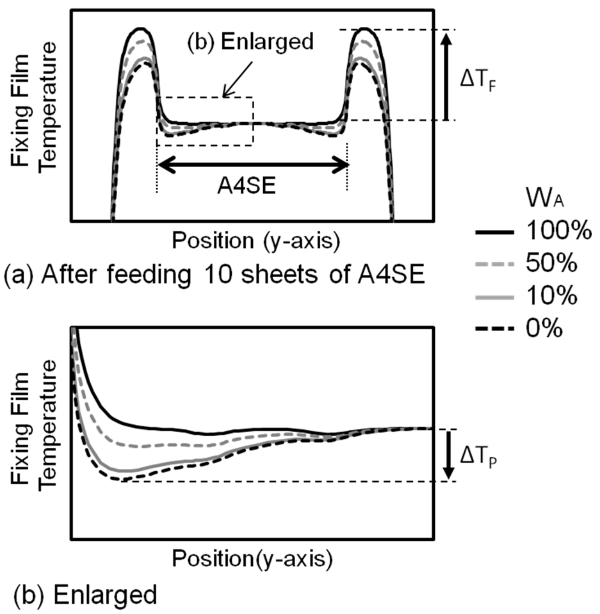

Figure 7. Temperature distribution of fixing film

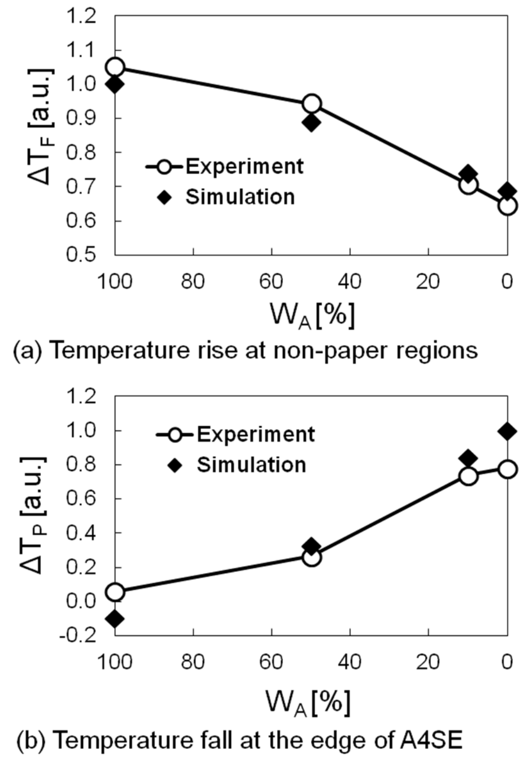

Figure 8. Comparison of experiments and simulations

Performance of Prototype Dual Heater

Lastly, a prototype of the dual heater design whose performance was estimated through simulation was constructed. The temperature rise at non-paper regions of the prototype dual heater was compared with the simulation results to verify that the prototype operated as expected. The results of the simulation and experiment of the dual heater are shown in Fig. 8.

Fig. 8(a) shows the temperature difference ΔT_F between the center of the paper-pass region and the maximum temperature area of the non-paper region (where ΔT_F is defined to be 1 for the temperature difference at W_A=100% in the experiment) of the fixing film at the downstream end of the fixing nip when the power supply ratio W_A to heating element A was varied. As with the simulation, in the experiment, the temperature rise at non-paper regions decreased as W_A was reduced.

Fig. 8(b) shows the temperature difference ΔT_P between the center of the paper-pass region and the minimum temperature area of the A4SE paper edge region (where ΔT_P is defined to be 1 for the temperature difference at W_A=0% in the simulation) of the fixing film at the downstream end of the fixing nip when the power supply ratio W_A was varied. As with the simulation, in the experiment, the temperature fall at the edge of A4SE increased as W_A was reduced.

These experiment results were found to be a close match to the estimation obtained through simulation, showing that the prototype operated as expected.

Summary

In this study, the effect of the dual heater technology in suppressing the temperature rise at non-paper regions was estimated through comparison with the conventional ODF heater by using three dimensional heat transfer simulation. The temperature rise at non-paper regions in a prototype dual heater was found to be a close match to the estimation obtained through simulation, showing that the prototype operated as expected.

References

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Author Biography

Hiroki Eguchi received his B.E. and M.E. degrees in Physics and Electronics from Osaka Prefecture University, Japan in 2007 and 2009, respectively. He joined Canon Inc. in 2009 and has been engaged in the development of electro-photography.