Paper: Energy Analysis for Backward Wrap-Nip Fuser for High-Speed Continuous Form Laser Printers

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Abstract

Backward wrap-nip fuser system has an advantage for super high-speed fusing in continuous form laser printers for heavy-duty use. The fuser is mainly composed of a heat roll, a back-up roll and a pre-heater. A nip region is formed between the two rolls. The fuser has a wrap region on its heat roll just after its nip region. Additional thermal energy is supplied in the wrap region and it enables to supply sufficient energy to toner on the continuous paper in super high-speed printing.

Local energy supply characteristics in the nip and the wrap regions are analyzed for designing the backward wrap-nip fuser system with effective energy supply. It is clarified that very high energy is supplied in very short period in the nip region and relatively gradual energy supply is made in longer period in the wrap region just after the nip region.

Introduction

Continuous form laser printers are mainly used for heavy-duty use in production printing. Productivity and reliability are the most important performances for such use. Faster print speed is needed for obtaining the more productivity. Improvement for print speed is the most important subject for developing super-high speed continuous form printers for heavy-duty use.

Fusing is the most important process in electrophotography to determine the print speed. Conventionally, a combined fuser system composed of a heat roll fuser without a wrap region and a pre-heater is used for continuous form laser printers. For obtaining print speed faster than 250ppm (pages per minute, about 1m/s), the system has a limitation for its heat supply. A fuser that has a wrap region just before or after its nip region has been appeared for achieving faster print speed and avoiding larger fuser system. We call the fuser system, which has the wrap region just before its nip region, a forward wrap-nip fuser system and the one, which has the wrap region just after its nip region, a backward wrap-nip fuser system in this paper. The forward wrap-nip fuser has an advantage for obtaining fixing strength. On the other hand, the backward wrap-nip fuser system has advantages on reliabilities for preventing image slur and paper handling at paper stop and start. For attaching greater importance to system balance, we employed the backward wrap-nip fuser system for our products. As a result, we have achieved the print speed faster than 400ppm. Furthermore, the backward wrap-nip fuser system has its possibility for achieving faster speed than it. The backward wrap-nip fuser system is discussed in this paper.

For establishing the backward wrap-nip fusing technology and its design methods, estimation on fusing energy in the backward wrap region compared to its nip region is needed. In this report, experiments are carried out for clarifying the fusing energy in the wrap region. The estimation method is derived from a combination of the estimated fusing energy in the wrap region by experiments and calculated fusing energy in the nip region by conventional analysis [1][2].

Fuser System for Continuous Feed

Fuser system makes the toner fixed on a paper in an

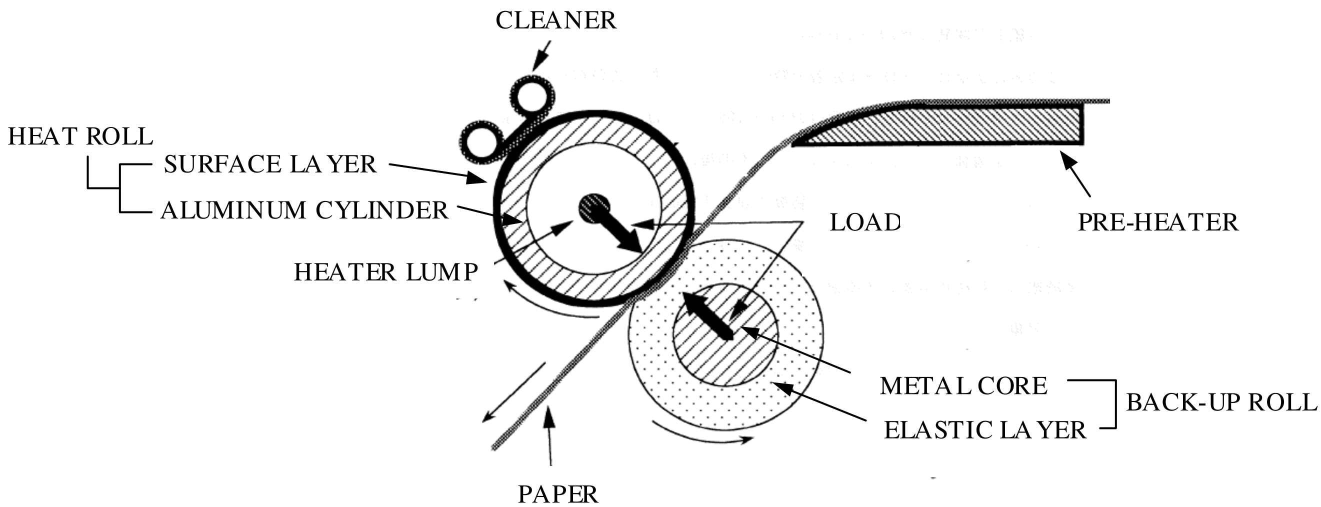


Figure 1. Schematic of Heat Roll Fuser System for Continuous Feed

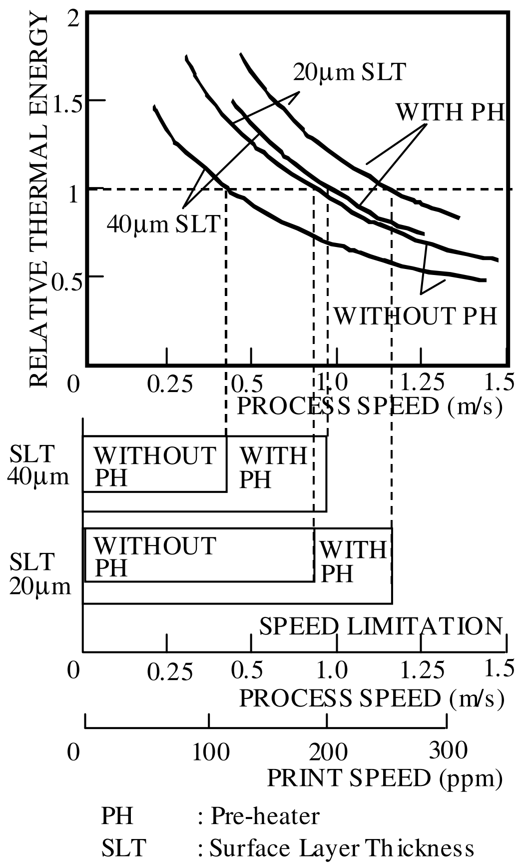


Figure 2. Relationship between Relative Thermal Energy and Process Speed.

electrophotographic process. The most important matter in the fuser system is obtaining sufficient fixing strength. Mainly two types of fuser principals are well known. One is non-contact fusing with xenon flashlights, another is contact fusing, in which heat and pressure are supplied to the toner. The later is called as a heat roll fusing system.

Figure 1 shows a schematic of a heat roll fuser system for super-high speed continuous feed. The system is mainly composed of a heat roll, a back-up roll and a pre-heater. The heat roll has a thin surface layer made of fluoride resin on an outer surface of an aluminum cylinder for preventing toner offset. Back-up roll has a elastic layer, normally made of silicone rubber, on an outer surface of a metal core. In high-speed fusing, small amount of offset toner is generated even though the fluoride surface layer is formed on the heat roll. Therefore an offset toner cleaner is installed on the heat roll. The heat roll and the back-up roll are pressed against each other and rotated. Elastic deformation of the back-up roll makes a nip region. Circumferential length, transit time and pressure of the nip region are called as nip width, nip period and nip pressure, each other. In high-speed fusing, the nip period comes to very short, several ms, even though a 80mm or larger diameter heat and a back-up rolls are employed. To obtain a sufficient thermal energy supplies to toner, high temperature as 180ºC or higher is set for the heat roll. The surface layer behaves as a thermal resistance in the nip region. The thermal resistance is lower as thinner surface layer.

Usually, thermal energy supplied only from the nip region is not satisfied in high-speed fusing. Therefore the pre-heater is installed prior to the heat and back-up rolls. The pre-heater is an aluminum hot plate, which temperature is set at 70-100ºC. The continuous paper is heated from back surface.

For faster speed, a wrap region is added on its heat roll just after or before its nip region. (They are not indicated in Figure 1.) Additional thermal energy is supplied in the wrap region and it enables to supply sufficient energy to toner on the continuous paper in super high-speed printing.

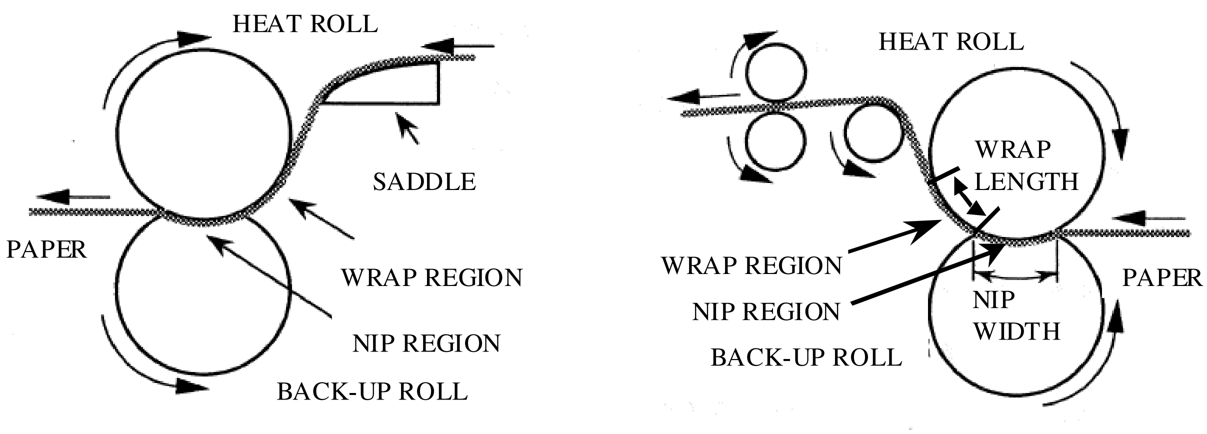
Speed Limitation in Fuser System without Wrap Region

Figure 2 shows calculated relationships between relative thermal energy and process speed of fuser systems for continuous feed without wrap regions. Process speed is equals to fixing speed. One dimensional analysis model is employed for the calculation. Details of the model are described in a previous literature. [1] Calculations are carried out for conditions of 20 and 40μm surface layer thickness with and without pre-heaters. Nip width and average pressure are defined as 10mm and $3.7x10^5 N/m^2$, respectively. The heat roll temperature is set at 190ºC. The pre-heater length and its temperature are assumed as 380mm and 80ºC at inlet /100ºC at outlet, respectively. Horizontal dots line in the figure shows thermal energy level to achieve fixing strength, where the relative thermal energy referred to 1. Above the line, the fixing strength is sufficient. In the condition of 40μm surface layer thickness, print speed can be possible up to 120ppm without pre-heater. Pre-heater is needed above this speed. However, 200ppm is a speed limitation even with pre-heater. In the condition of 20μm surface layer thickness, print speed can be possible up to 190ppm without pre-heater. Pre-heater is needed above this speed. However, 260ppm is a speed limitation even with pre-heater.

Backward Wrap-Nip Fuser

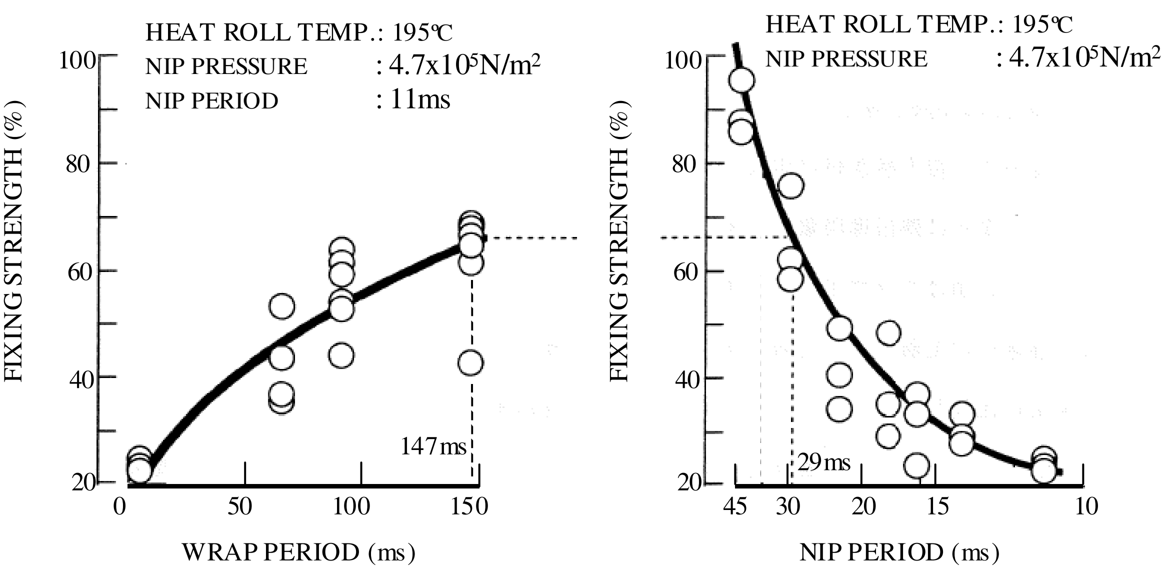
Figure 3 (a) and (b) show schematics of a forward wrap-nip and backward wrap-nip fusers, respectively. Circumferential length and transit time of the wrap region are defined as wrap length and wrap period, respectively, in this paper. As shown in the figures, a forward wrap-nip fuser system has the wrap region just before its nip region, and a backward wrap-nip fuser system has the wrap region just after its nip region. Additional thermal energy is supplied in the wrap region and it enables to supply sufficient energy to toner on the continuous paper in super high-speed printing. The forward wrap-nip fuser has an advantage for obtaining fixing strength because nip pressure is applied for fused toner. The backward wrap-nip fuser system has advantages on reliabilities for preventing image slur and paper handling at paper stop and start because toner is fixed in the wrap region where no pressure is applied. For attaching greater importance to system balance, we employed the backward wrap-nip fuser system for our products. The backward wrap-nip fuser system is discussed in this paper.

To design the backward wrap-nip fuser system, it is necessary to know fusing energy supply level in the wrap region. We established fuser design method for the nip region using analysis



(a) Forward Wrap-nip Fuser *(b) Backward Wrap-nip Fuser*

Figure 3. Schematic of Wrap-nip Fuser System.



(a)Nip Region with Backward Wrap Region. *(b)Nip Region without Wrap Region.*

Figure 4. Test Results of Fixing Strength.

for fusing energy. [2] In this paper, the method for fusing energy estimation is to be extended to the backward wrap-nip region.

Using a test fuser unit, comparison between the backward wrap-nip fusing and the nip fusing is carried out. The test results are shown in Figure 4 (a) and (b). Fixing strength with wrap period in the wrap-nip fuser is shown in Figure 4 (a). In this test, the nip period is fixed as 11ms. Fixing strength with nip period without the wrap region is shown in Figure 4 (b). From these two charts, the fixing strength at 147ms of the wrap period, shown in Figure 4 (a), and that of 29ms of the nip period, shown in Figure 4 (b), is corresponding. This means that fusing energy of 147ms of

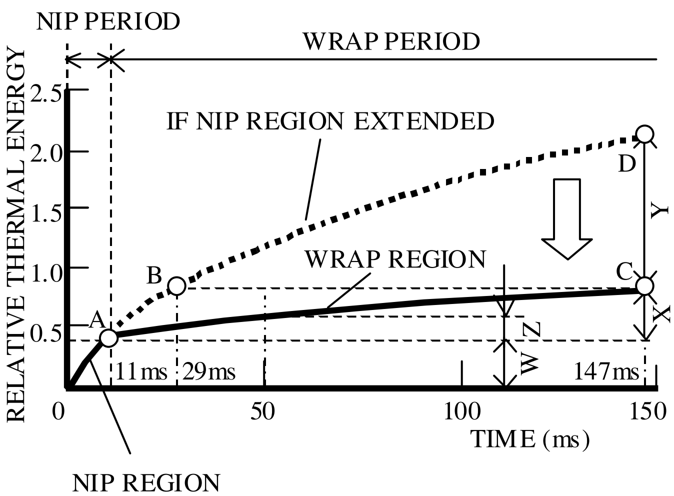


Figure 5. Caluclated Results of Relative Thermal Energy with time.

the wrap period with 11ms nip period and 29ms nip period are equivalent.

Figure 5 shows calculated relative thermal energy with time after nip region. Point A in the figure shows 11ms nip period, which is an inlet of the wrap region of the condition shown in Figure 4 (a) and point B shows the results of 29ms nip period, which is condition shown in Figure 4 (b). Time of point C is the outlet of the wrap region of the condition shown in Figure 4 (a). The energy level Points B and C must be same. Therefore the energy supply history in the wrap region can be shown as a curve from Points A to C. Thus, fusing energy in the wrap region can be clarified. Thus, it is observed that very high energy is supplied in very short period in the nip region and relatively gradual energy supply is made in longer period in the wrap region just after the nip region. Curve B to D is an extended line of Curve 0 to B. This curve shows an energy supply history in case that whole region is composed from nip region. Comparing between Curves A to D and A to C, the fusing energy in the wrap region can be estimated as 1/4 (= X / (X+Y)) of that in the nip region.

Using the chart shown in Figure 5 and defining the wrap length, the fusing energy supply in the nip and backward wrap regions can be estimated. Practically considering paper handling performance, the wrap length should be 3-4 times of the nip width. Assuming 50ms for the nip and wrap periods in Figure 5, fusing energy added in the wrap region runs up about 40% (= Z / W) of the nip region.

The fusing energy estimation in the backward- wrap region can be carried out. Thus, the super high-speed continuous feed laser printers, exceeding 1.6m/s process speed, can be achieved.

Conclusions

For establishing the backward wrap-nip fusing technology and its designing methods, estimations on fusing energy in the backward wrap region compared to its nip region are examined. The estimation method is derived from a combination of estimated fusing energy in the wrap region by experiments and calculated fusing energy in the nip region by conventional analysis. As a result, it is clarified that the fusing energy in the backward wrap region can be estimated as 1/4 of that in the nip region.

References

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Author Biography

Teruaki Mitsuya was born in Aichi-Pref., Japan in 1957. He received his BE, ME and Dr. Eng. degrees in 1980, 1984 and 1997, each other. He has been researching imaging technologies in laser printers, in Hitachi, Ltd. from 1984, California Inst. Tech. from 1994, Hitachi Koki Co., Ltd. from 1995, Hitachi Printing Solutions, Ltd. from 2002 and Ricoh Printing Systems, Ltd. since 2004. He is a member of IS&T, ISJ, ASME, JSME, etc.