Color Fusing Technology Using Induction Heating

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A unique color fusing technology using induction heating has been developed, which has been adopted in a newly released one-pass color laser printer. The color fusing unit consists of a thin fusing belt made of heat resistant resin containing metal, a heating roller with low thermal capacity, a fusing roller, and a pressure roller to press the fusing roller with the fusing belt in between. An induction heater is disposed along and adjacent to the outer circumference of the fusing belt and heating roller. The newly developed fusing belt has a low thermal capacity, with a thickness of only several hundred micrometers, and has a structure that self-heats at high efficiency, since eddy currents are generated inside the belt by electromagnetic induction. In addition, the eddy currents generated by the alternating magnetic field heats the heating roller. This design shortens the warm-up time of the fusing unit from cold start to only 20 sec. This color laser printer eliminates the need to preheat the fusing unit during stand-by time by employing the induction heating technique and achieves energy saving of 90% or more compared with conventional printers.

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Introduction

The WORKiO™ KX-CL500/KX-CL510 series color laser printers featuring a tandem printing system was released in early 2003. This series realized faster warm-up time than conventional printers due to the utilization of our original IH (induction heating) fusing technology and also featured compact and light weight. In the KX-CL500/KX-CL510 series, the printing rate is 17 ppm for color and 21 ppm for monochrome printing, respectively, and the IH fusing technology is optimized to achieve stable and high fusing quality.

The main feature of the IH color fusing unit installed in the printer is a configuration in which an induction heater is located at the outer circumference of a fusing belt. In addition, the fusing belt is made of heat resistant resin base including metal.

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Due to this creative configuration, heat generation by electromagnetic induction gives high efficiency which enables the fusing belt to be directly and rapidly heated. Even when starting cold, the printer attains 20 sec. warm-up time.

In a color laser printer with this IH fusing unit, therefore, preheating of the fuser can be eliminated and the overall power consumption is suppressed to 9 watts at its power save mode. This represents drastic energy saving compared with conventional printers.

The Technical Challenges of Color Fusers

A conventional laser printer employs a heat roller fusing system illustrated in Fig. 1. A halogen lamp is installed inside a heating roller and warms the roller by radiant heat. For color printing, in particular, both the heating roller and pressure roller need to have a large diameter to secure a wide nip area and ensure stable fusing quality. In addition, the heating roller is designed to become concave in the nip area to enable easy separation of the printed paper at the exit of the area. This design, however, gives a high thermal capacity to the heating roller since the roller is covered by a thick rubber layer with low heat conductivity.

This arrangement causes a problem: it takes a long time for the heating roller to reach the predetermined control temperature. To solve this problem in conven-

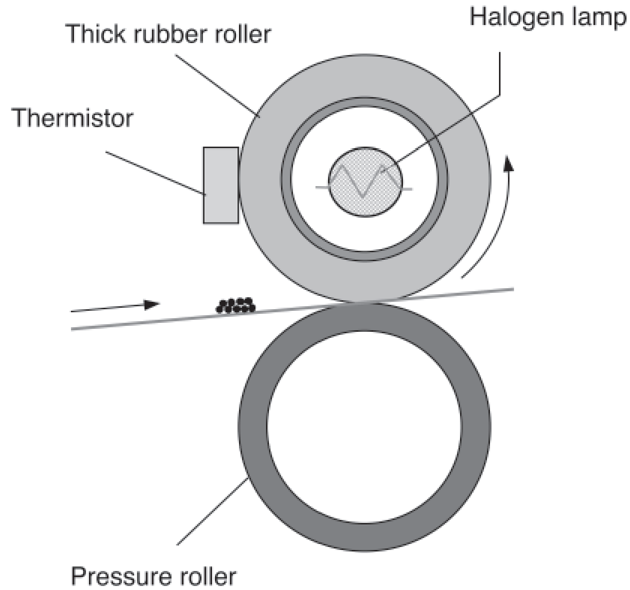


Figure 1. Schematic of conventional heat roller fusing

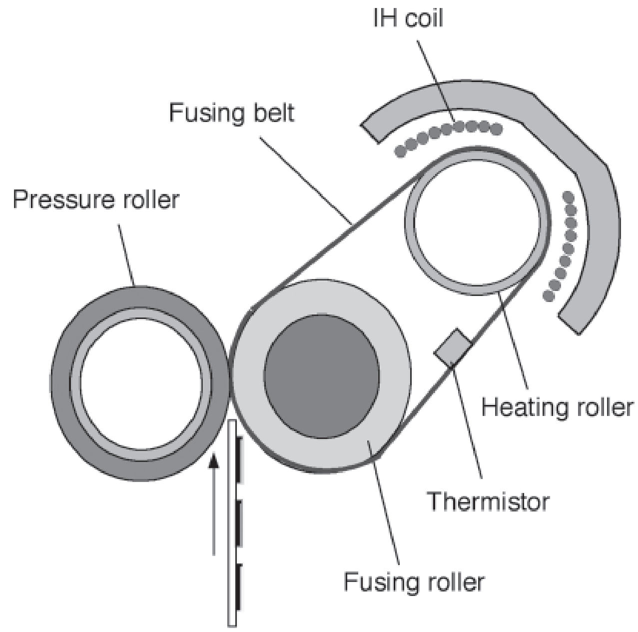


Figure 2. Construction of IH color fuser

TABLE I. Specification of IH Color Fuser

Parts	Diameter [mm]	Thickness [mm]	Material
Heating roller	20	0.4	Iron
Fusing roller	30	5.0	Silicone sponge
Pressure roller	30	2.0	Silicone rubber
Fusing belt	45	0.26	PTFE+Silicone+PI

TABLE II. Performance of IH Color Fuser

Items	Specifications
Process speed	Color: 100 mm/s
	Monochrome: 125 mm/s
Input power	900 W or less
Warm-up time	20 sec. or less

tional models, the heating roller is preheated during the waiting time to shorten the warm-up time. However, pre-heating in this way wastes a considerable amount of power.

IH Color Fuser

Construction

To solve these technical challenges, an IH color fusing unit with short warm-up time has been developed: that is, the device warms up very rapidly without the need for pre-heating during the waiting time. The configuration of our newly developed IH color fusing unit is shown in Fig. 2. The device consists of a thin belt made of heat resistant resin including metal, a heating roller with low thermal capacity, a fusing roller made of foamed material, and a pressure roller which applies pressure to the fusing roller through the fusing belt. An induction heater is disposed along and adjacent to the outer circumference of the fusing belt and the heating roller. The advantage of this fusing unit is that the toner fusing portion and belt heating portion are completely separated functionally from each other. This configuration enables the reduction of the thermal capacity of the heating roller by the use of a thin metal roller with high heat conductivity. In addition, a temperature detecting thermistor can be located inside of the fusing belt between the heating roller and the fusing roller. The inside location of the thermistor obviates any scratching wear to the belt surface that might affect image quality of prints. Precise thermal control can be obtained with inside-mounted thermistor, because the thickness of the fusing belt is so thin that the temperature difference between outer and inner surfaces of the belt may be negligible. Tables I and II show an outline of the construction of the IH color fuser and its operational specifications, respectively.

Figure 3 shows the state of contact between two rollers at the fusing nip area. For paper self-detachment, the fusing roller should be softer than the pressure roller. This design creates a wider fusing nip and enables easier paper self-detachment. Owing to the concave shape on the fusing roller side, the paper is easily peeled off when leaving the nip area. This leads to easy detachment of the paper.

Heat Generation by Induction Heating

The heating principle of the IH fusing unit is described with reference to Fig. 4. High frequency alternating current supplied to the IH coil produces an alternating magnetic field, which creates eddy currents in the conductive portion of the fusing belt and heating roller. Due to Joule heating caused by these eddy currents, both the fusing belt and fusing roller self-heat. Figure 5 shows a simulation result for the electromagnetic field near the IH coil. This illustrates that the magnetic field induced by the IH coil is concentrated on the heating roller and the magnetic field generated at the back of the IH coil is absorbed by the ferrite cores.

IH Coil Unit

The IH coil unit is an important factor in the design, since the electromagnetic field induced by the IH coil is greatly influenced by the coil and cores arrangements. Figure 6 shows dependence of the coil and core shapes on electric characteristics. In the a-type, E-shaped core, too much current is required for driving so that destruction of a power transistor IGBT (Insulated Gate Bipo-

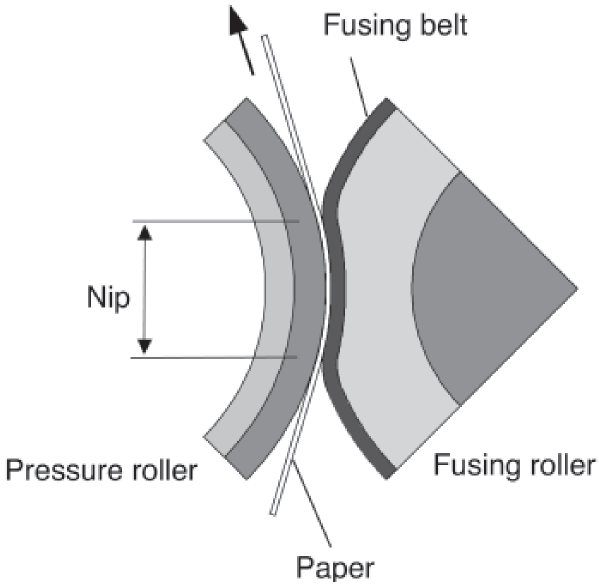


Figure 3. Profile of roller deformation at nip region

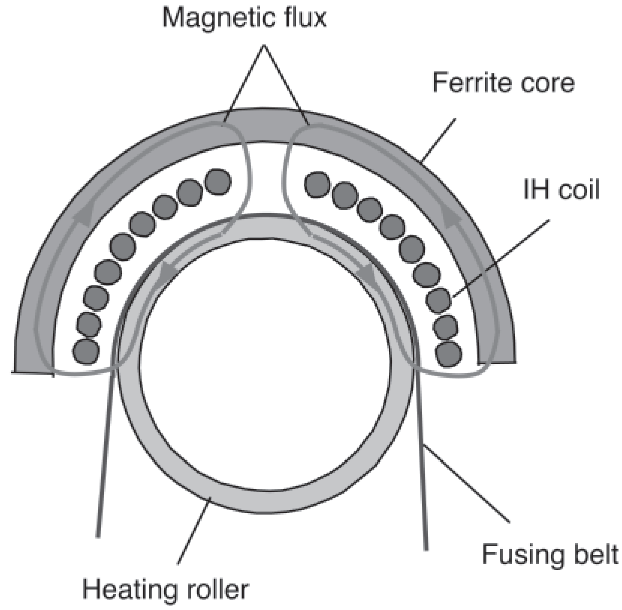


Figure 4. Principle of heat generation by induction heating

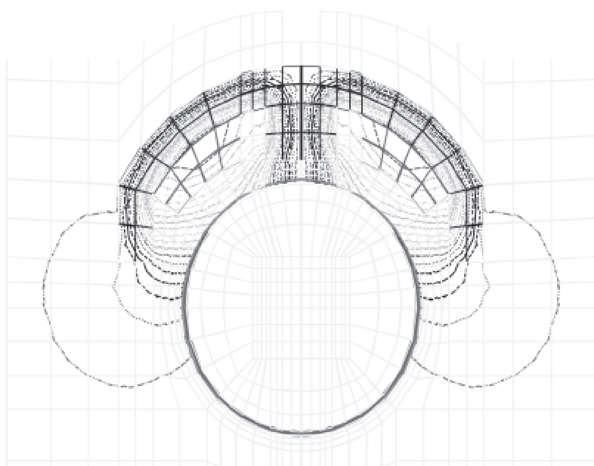


Figure 5. Simulated magnetic field

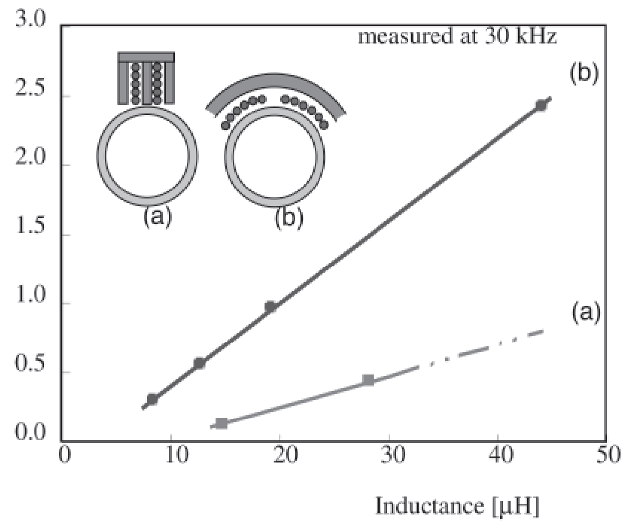


Figure 6. Comparison of coil and cores arrangements

lar Transistor) will occur. In the b-type configuration, the coil is wound along the outer circumference of the roller. In this type, the load resistance nearly tripled with the same inductance. This indicates that the b-type arrangement generates greater magnetic binding strength and magnetic energy is being converted into Joule heat at higher efficiency.

Table III shows a summary of the specifications of the IH coil unit. General purpose litz wire, which is reasonably priced and easy for terminal preparation, is used for the IH coil. The heat loss in the coil is about 5%. In addition, by optimizing both inductance and resistance, the coil is designed so that the current is limited to 50 A or less, even at peak value, and the heat loss and noise at the IGBT are suppressed.

In the b-type arrangement, the sum of energy losses in the coil and control circuit is about 10%, meaning that the heat generation efficiency is over 90%.

TABLE III. Specification of IH Coil Unit

Items		Specifications
Wire	Grade of heat resistance	H (180°C)
	Diameter	0.19 mm
	Number of strands	40
Operating frequency		20~50 kHz
Coil current		50 A or less
Inductance		42 μH at 20 kHz
Load resistance		1.45 Ω at 20 kHz

Fusing Belt

The fusing belt is made by covering PI (polyimide) heat resistant resin base with a silicone rubber layer and a PTFE surface releasing layer. The structure of the fusing belt is shown in Fig. 7. A resin based belt is more resistant than a metal based belt, e.g., a nickel belt, to

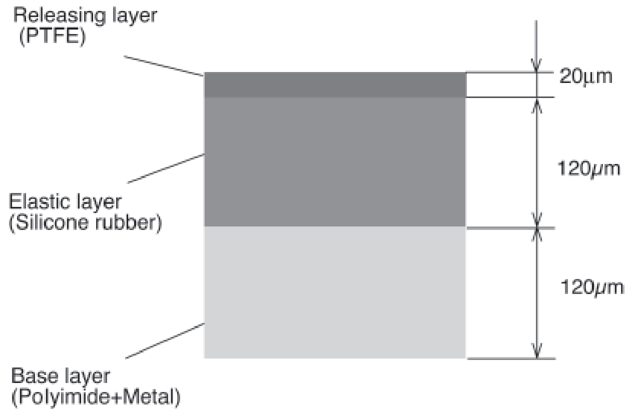


Figure 7. Layer construction of fusing belt

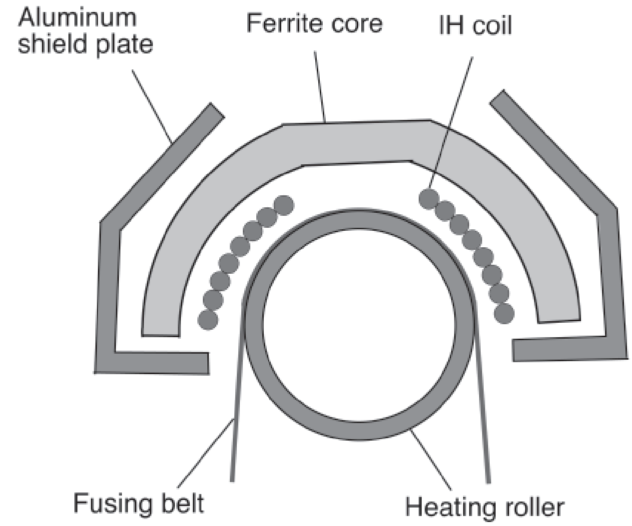


Figure 8. Construction of EMC control

TABLE IV. Comparison of Base Layer Material

Base layer material	PI	PI+Metal
Heat generation efficiency [%]	84	90
Warm-up time [s]	22	18

repeating fatigue at the nip portion and mechanical load in the thrust direction generated during rotation. This mechanical resistance of the resin based belt, therefore, increases life of the belt. The newly developed fusing belt is made of PI heat resistant resin base containing metal. As a result, the belt self-heats by electromagnetic induction, and a high-speed thermal response is obtained due to efficient heat conduction to the belt surface. Table IV shows the result of a comparison of the heat generation efficiency between a metal containing belt and non-metal containing control. Metal enhances heat generation efficiency, and shortens the warm-up time from 22 sec. to 18 sec.

Features of Outer-type IH versus Inner-type IH

As shown in Fig. 2, the newly developed IH coil unit has an outside heating structure whereby the IH coil is located along the outer periphery of the heating roller. Table V also describes another type,[1–3] with an inside heating structure in which the IH coil is disposed along the inner surface of the heating roller.

The advantage of an outside heating structure over an inside heating structure is that the temperature rise of the coil due to radiant heat from the heating roller is smaller and the coil can be cooled more easily. A general purpose grade coil, which is reasonably priced and produced in high volume, can therefore be employed.

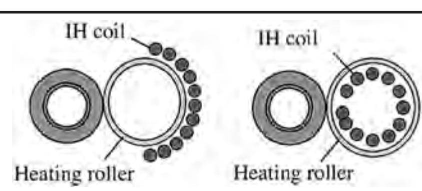
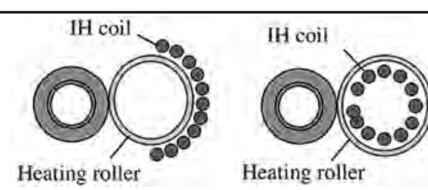
In addition, maintenance cost is minimized because the fusing unit can be replaced, leaving the IH coil portion in the printer body. Furthermore, heat generating roller size can be made smaller. On the other hand, the outside heating structure raises an issue concerning electromagnetic compatibility. Magnetic flux generated by the coil must be blocked so as not to leak outside, since the IH coil is not surrounded by the conductive roller.

IH Control Technologies

EMC Control

Because the IH coil of the newly developed IH color fuser was not surrounded by a conductive roller, a configuration for blocking magnetic flux leakage was devised. Figure 8 shows the magnetic shield configuration. To suppress the leakage of the magnetic flux, the aluminum shield plate is installed outside of the coil. Since the eddy currents generated when leaked flux passes through the shield plate induce magnetic fields in the direction opposite to the coil generated field, the leaked flux is canceled. By this principle magnetic flux leakage was reduced by 20 dB or more at the fundamental frequency compared with the version without the aluminum plate.

TABLE V. Outer-Type IH versus Inner-Type IH

Structure	Outer-type IH	Inner-type IH
		
Coil temperature	<150°C (Heating roller at 170°C)	>200°C (Heating roller at 170°C)
Fuser maintenance	Replaced without IH coil unit	Replaced with IH coil unit
Small size capability (Heating roller)	Possible	Difficult
Electromagnetic Compatibility; EMC	Outer shield member required	Absorbed by heating roller

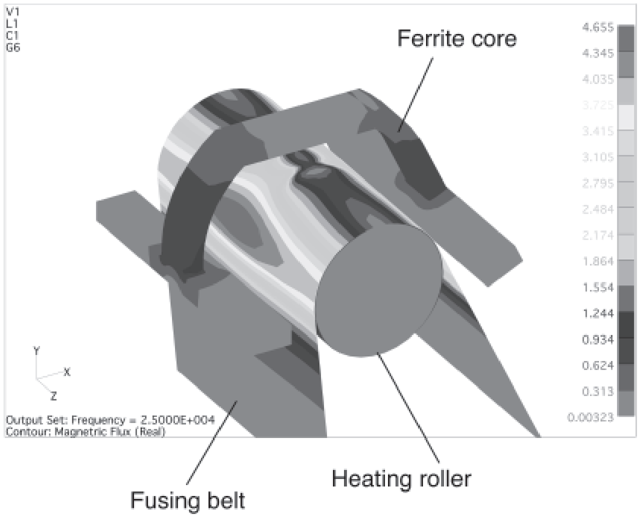


Figure 9. Simulated magnetic flux distribution

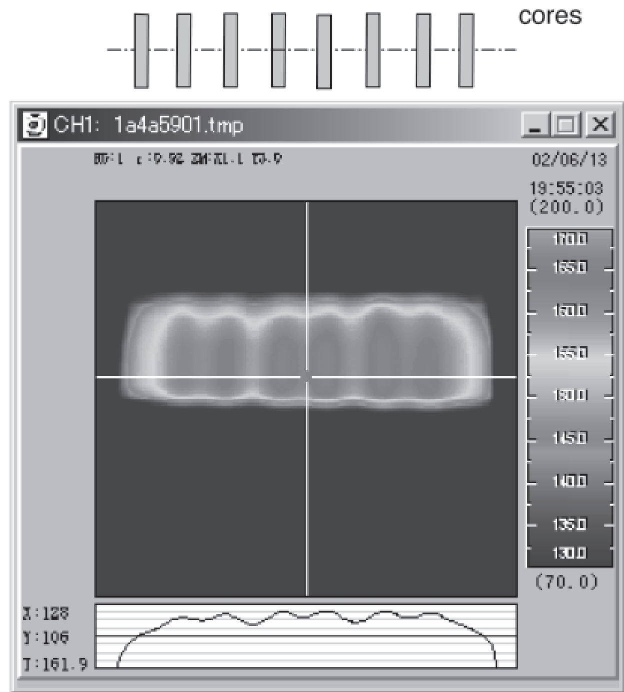


Figure 10. Temperature distribution in case of straight arrangement

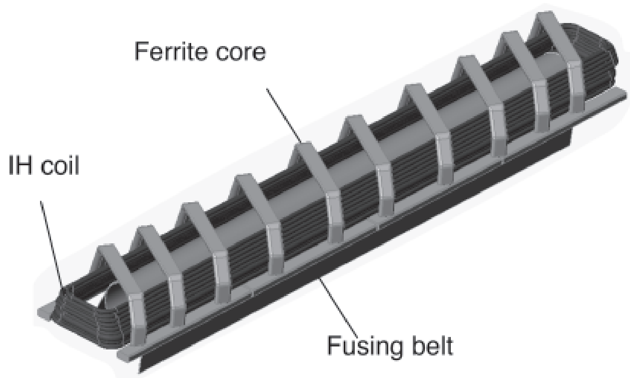


Figure 11. Construction of ferrite core

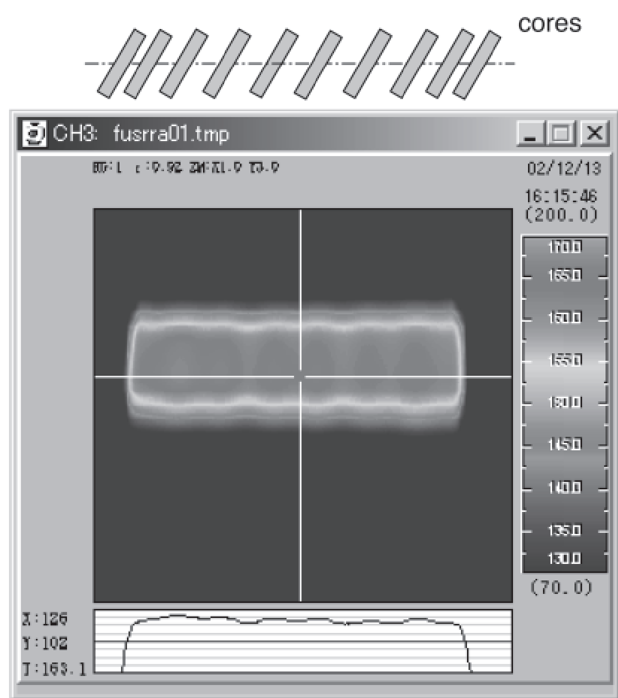


Figure 12. Temperature distribution in case of slant arrangement

Magnetic Flux Control

In the IH color fusing unit, several ferrite cores are arranged behind the IH coil to heat the fusing belt and heating roller efficiently. Figure 9 is a simulation result of magnetic flux density distribution on the fusing belt. It is seen that the flux concentration around the ferrite cores generates non-uniformity in the flux distribution. Under these conditions, as shown in Fig. 10, temperature non-uniformity occurs in the fusing belt in the direction of rotation. Figure 10 shows the surface temperature of the belt just after warming up, as measured by an infrared thermometer, and the temperature distribution along the axis.

To overcome this temperature non-uniformity, the ferrite cores installed behind the IH coil were arranged slanted to the roller axis as shown in Fig. 11. To prevent a temperature drop at both ends of the fusing belt owing to heat radiation from the belt and heat loss from the ends, the distance between cores is made narrower at the both ends compared with the center, and the ferrite cores installed behind the IH coil are connected by the cores on each side. As a result, flux from the coil is almost evenly distributed along the roller axis, making the temperature of the belt surface uniform. Figure 12 shows the surface temperature of the belt under the conditions just after warming up, again measured by an infrared thermometer, as well as temperature distribution along the axis when the cores are slanted to the roller axis. The uniformity of the surface temperature was improved to within 5°C compared with the previous arrangement of cores.

Conclusion

An outer coil type IH belt fuser has been developed. Warm-up time from cold starting of the unit has been reduced to only 20 sec. The color laser printer in which this IH fusing unit is installed achieves a greater than 90% energy savings compared with conventional machines. In this development, the following original technologies have been developed.

1. Extended durability and high heat generating efficiency are obtained with newly developed conductive polyimide film,
2. With respect to the electromagnetic compatibility issue, the leakage of the magnetic flux can be suppressed by using aluminum shield plate, and
3. Improved temperature uniformity is obtained by a unique arrangement of the ferrite cores.

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