The Horizontal Banding Image related to the Surface Heating Fuser System

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Abstract

The surface heating fuser, required in the EP printer from the energy saving standpoint, sometimes causes the horizontal banding image. This type of banding is not seen with conventional fuser such as the heat roller type. We found that the root cause of this phenomenon is the AC current leakage from fuser to transfer area. This paper reports that the RC circuit model between fuser and transfer area can simulate this phenomenon well. According to this model, solutions are as follows;

1. To increase the reactance of fuser heater and film, preventing the AC current leakage to the media.

2. To add the by-pass circuit from fuser film inside to the ground, preventing the AC current leakage to the media.

3. To add the by-pass circuit from pressure roller to the ground, preventing the AC current leakage to the media.

Introduction

SURF system has built a firm reputation as energy-saving fusing technology. However, the SURF system might cause a horizontal banding image, because the SURF system has a fusing heater that is close to the fusing nip, and the AC current leakage is easily transmitted to the fusing nip and to a transfer part through the media, and oscillates transfer voltage. On the other hand, the conventional fuser such as the heat roller type has a halogen lamp that is far from the fusing nip. Therefore, this kind of banding does not occur. This paper reports that the RC circuit model between fuser and transfer area can simulate this phenomenon well.

The Mechanism of Banding

Fig.1 shows the cross sectional image between fuser and transfer area. Here, we explain the case of SURF system. The AC voltage inputted from the AC power supply is transmitted to the media through the heater substrate and the fusing film (I of Fig.1). Moreover, AC voltage is transmitted from the fusing nip to the transfer nip through the media, in the condition that resistance of the media is remarkably lowered by high temperature and high humidity (II of Fig1). Consequently, AC voltage is overlapped with DC voltage of transfer, and transfer voltage is oscillated (Fig.2). This oscillation of transfer voltage turns into the change of transfer efficiency, and causes a difference of density (banding) on the image. A portion of dark density is caused by high transfer voltage, and a portion of light density is caused by low transfer voltage.

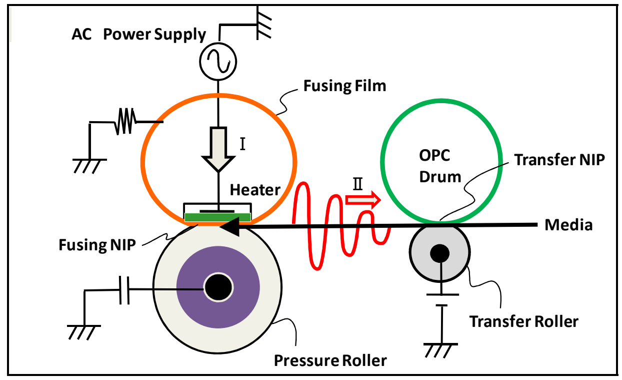

***Figure1**. Cross sectional image between fuser and transfer*

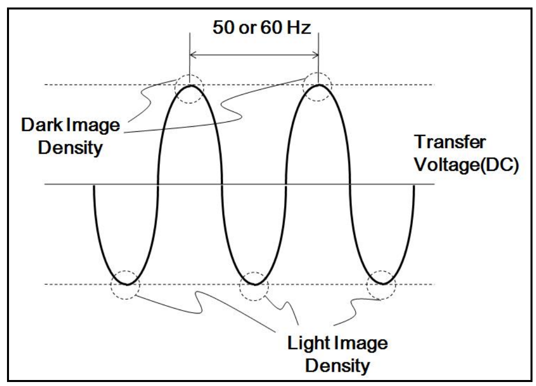

***Figure2**. Transfer voltage overlapped with AC voltage*

Fig.3 shows the image of the banding. d1 is the distance from transfer area to fuser. Before a leading edge of media reaches fusing nip, banding does not occur. d2 of the dark and light density on the image shows the cycle of the banding. d2 is calculated according to the following equation:

$$d2 = v_p/f$$

where v_p is the transportation speed of media. f is the frequency of the AC input voltage. For example, in the case of 50Hz, 100 mm/sec, d2 becomes 2.0mm.

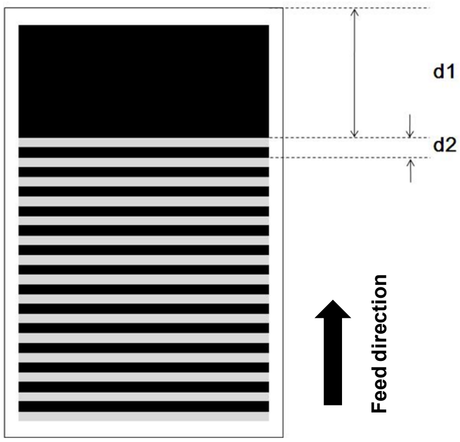

Figure3. *Banding image on media.*

RC model between fuser and transfer

We assume that the banding is related to oscillation of transfer voltage, and the banding level is proportional to the size of AC amplitude in transfer nip. Fig.4 shows the RC circuit between fuser and transfer area. By using this circuit model, we can predict the banding level. We will describe how to calculate the Resistance(R) and Capacity(C).

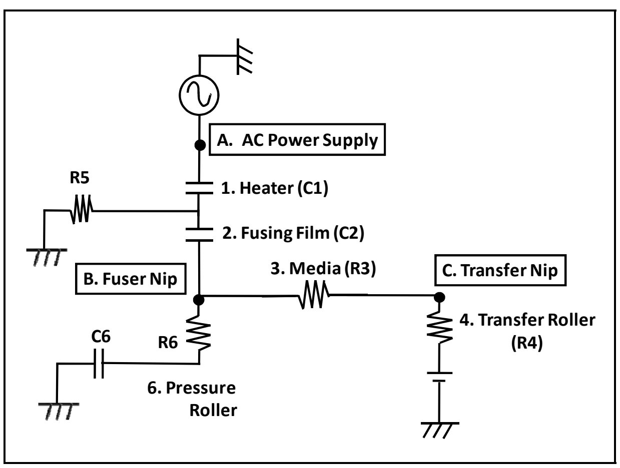

Figure4. *RC circuit model between fuser and transfer*

1. Heater (C1)

Fig.5 shows the image of the fusing nip. Heater consists of three layers that are substrate of insulation, pasted heating element on a substrate, and the cover layer on the pasted heating element. Capacity C1 is calculated according to the following equation:

$$C1 = \varepsilon_1 S / d3$$

where ε_1 is the dielectric constant of the substrate. S is the area of the heating element. d3 is the thickness of the substrate.

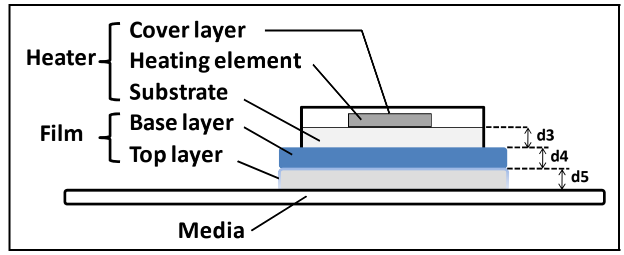

Figure5. *Image of the fusing nip*

2. Fusing film(C2)

Fusing film consists of two layers that are the base layer such as PI or SUS, and the top layer such as PFA or Rubber. Capacity C2 is calculated according to the following equation:

$$C2 = C2a \times C2b / (C2a+C2b)$$

Where: C2a is base layer's capacity. C2b is the top layer's capacity.

In the case that the insulating film such as PI is used as the base layer, capacity C2a is calculated according to the following equation:

$$C2a = \varepsilon_2 S / d4$$

where ε_2 is the dielectric constant of the base layer. S is the contact area of the film and the heating element.d4 is the thickness of the base layer.

In the case that the conductive film such as SUS is used, it is possible to disregard it on the circuit. In the case that resistive film such as PI added filler, it may be approximated as a resistance object, or it may be approximated by RC parallel model.

On the other hand, in the case that the insulating PFA or rubber is used as the top layer, capacity C2b is calculated according to the following equation:

$$C2b = \varepsilon_3 S / d5$$

where ε_3 is the dielectric constant of the top layer. S is the contact area of the film and the heating element.d5 is the thickness of the top layer.

In the case that the top layer is resistive, it may be approximated by RC parallel model as mentioned above. In the case that the top layer is conductive, it is possible to disregard it on the circuit.

3. Resistance of media from fuser to transfer (R3)

R3 is the resistance of media from fuser to transfer, so that it is proportional to the distance d1. R3 is calculated according to the following equation:

R3 = σ d1

where σ is the resistance of media for each unit length.d1 is the distance from fuser to transfer.

In high temperature and high humidity where the banding might be occurred, the resistance (σ) was measured as 1(MΩ/mm). For example, in the case of 60mm (d1), R3 becomes 60MΩ.

4. The transfer roller (R4)

Resistance R4 of transfer roller is measured by applying voltage between shaft and electrode roller which is contacted to transfer roller surface.

5. Resistance between fusing film and ground film (R5)

R5 is resistance between fusing film and ground. If the inside of the fusing film is not grounded, R5 is disregarded on the circuit. If the capacitor is connected with R5 in series or in parallel, corresponding circuit should be created accordingly.

6. Resistance and Capacity between Pressure roller and ground (R6,C6)

R6 is resistance between Pressure roller and ground. C6 is capacity between Pressure roller and ground. If the Pressure Roller is not grounded, R6 and C6 are disregarded on the circuit. If the capacity is connected in parallel like the provisional publication of a JP2006-195003, corresponding circuit should be created accordingly.

In this model, these calculated capacities C are converted into reactance Xc according to the following equation:

$$Xc = 1 / (2\pi fC)$$

where π is the circular constant. f is frequency of the AC input voltage. C is calculated capacity as mentioned above.

And we calculate the AC amplitude (in percentage) in transfer nip, when the input AC amplitude was assumed to be 100%. As mentioned above, banding level can be predicted by this percentage, and be called AC transmission rate.

Correlation between AC transmission rate and banding level

Table.1 shows a correlation between AC transmission rate calculated from the RC circuit, and banding level of eleven printers (A～K) under development. The realistic range of heater reactance Xc1, film reactance Xc2, and media resistance R3 are 200MΩ or less. The print conditions are as follows. able.1 shows that AC transmission rate correlates with the banding level, and if the AC transmission rate is less than 30%, the banding does not observed.

[The print conditions]
Print environment: 30℃/80% RH
Media：STEINBEIS RECYCLING COPY 80g/m^2
(acclimated for 48 hours, σ = 1.0MΩ/mm)
Print pattern: Solid Black
Print mode: Plain paper mode (Full Speed)
Input voltages: AC200V (f = 50Hz)
Voltage of transfer : 700V

Correlation between AC transmission rate and reactance Xc

We changed the heater reactance Xc1, film reactance Xc2, and media resistance R3 in printer K (which showed the worst result). Fig.6 shows that AC transmission rate is inversely proportional to heater reactance Xc1, film reactance Xc2, and media resistance R3. If the heater reactance Xc1 and film reactance Xc2 become large, then less AC current is transmitted to the fusing nip. As a result, the AC amplitude in transfer nip becomes low. And if the media resistance R3 becomes large, then less AC current is transmitted from fuser nip to transfer nip. As a result, the AC amplitude in transfer nip becomes low.

Table.1 Correlation between AC transmission rate and banding level

		A	B	C	D	E	F	G	H	I	J	K
Heater Reactance **(Xc1)**	$Xc1=1/(2\pi\ f\ C1)$	45 MΩ	33 MΩ	7 MΩ	10 MΩ	6 MΩ	30 MΩ	5 MΩ	6 MΩ	6 MΩ	4 MΩ	6 MΩ
Film Reactance **(Xc2)**	$Xc2=1/(2\pi\ f\ C2)$	56 MΩ SUS Rubber	25 MΩ SUS Rubber	under 1MΩ PI added filler	under 1MΩ PI added filler	under 1MΩ PI added filler	34 MΩ SUS Rubber	under 1MΩ PI added filler	17 MΩ PI	59 MΩ SUS Rubber	33 MΩ SUS Rubber	64 MΩ PI Rubber
Media Resistance **(R3)**	R3 = σ d1	54 MΩ	54 MΩ	128 MΩ	115 MΩ	55 MΩ	184 MΩ	60 MΩ	55 MΩ	107 MΩ	108 MΩ	84 MΩ
Reactance between Pressure roller and Ground **(Xc6)**	$Xc6=\{(2\pi\ f\ C6)^2+R6^2\}^{1/2}$	400 MΩ	400 MΩ	1 MΩ	1 MΩ	3 MΩ	200 MΩ	3 MΩ	16 MΩ	200 MΩ	400 MΩ	400 MΩ
Resistance between Film and Ground **(R5)**	R5	2 MΩ	2 MΩ	–	–	–	–	–	–	200 MΩ	400 MΩ	400 MΩ
AC transmission rate (%)		**3%**	**5%**	**14%**	**17%**	**28%**	**33%**	**33%**	**38%**	**64%**	**72%**	**73%**
Banding		**not observed**	**not observed**	**not observed**	**not observed**	**not observed**	**observed**	**observed**	**observed**	**observed**	**observed**	**observed**

In other words, amount of AC current leakage from AC power supply to transfer nip is inversely proportional to the size of electrical impedance which is connected with the circuit from AC power supply to transfer nip in series.

In this case of Printer K, if we change these parameters Xc1, Xc2, R3 in realistic range of less than 200MΩ, the AC transmission rate did not reach below than 30%. In such a case, we should change Xc1, Xc2, R3 at the same time. Otherwise, we should change the resistance R5 or the reactance Xc6, as follows.

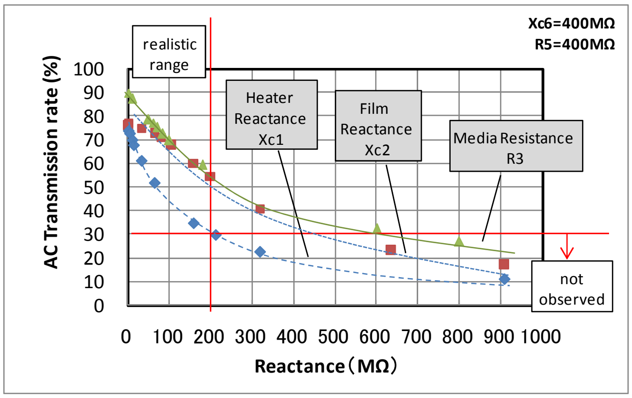

Figure6. *The correlation between the AC transmission rate and reactance Xc1, Xc2 and resistance R3*

We changed the resistance R5 on the by-pass circuit from fusing film inside to the ground, and reactance Xc6 on the by-pass circuit from Pressure roller to the ground, in printer K (which showed the worst result). Fig.7 shows that AC transmission rate is proportional to the resistance R5 and reactance Xc6. If the ground resistance R5 in fusing film becomes low, the AC current transmits to the ground through the resistance R5, then less AC current is transmitted from fusing nip to transfer nip. As a result, the AC amplitude in transfer nip becomes invisible level. And if ground reactance Xc6 in Pressure Roller becomes low, the AC current transmits to the ground through the reactance Xc6, then less AC current is transmitted to the transfer nip. As a result, the AC amplitude in transfer nip becomes invisible level.

In other words, amount of AC current leakage from AC power supply to transfer nip is proportional to the size of electrical impedance which is connected with the circuit from AC power supply to transfer nip in parallel.

In this case of Printer K, if we change the resistance R5 from 400MΩ to less than 5MΩ, the AC transmission rate reach below than 30%. Otherwise if we change the resistance Xc6 from 400MΩ to less than 30MΩ, the AC transmission rate reach below than 30%.

As mentioned above, we can simulate the correlation between AC transmission rate and reactance Xc. Therefore, we can select the effective parameters to control the AC transmission rate to be less than 30%, in which banding is not observed.

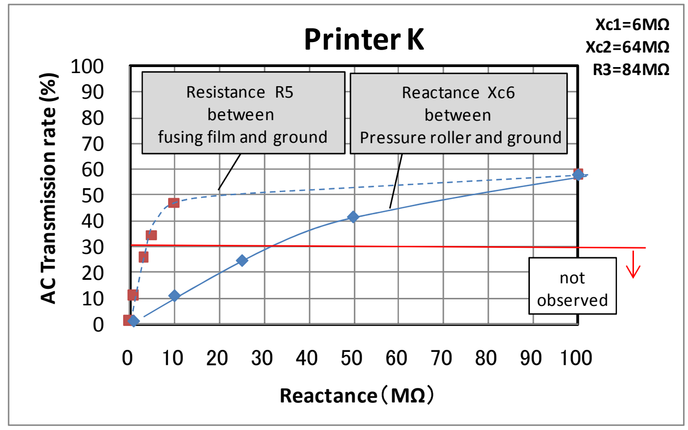

Figure7. *The correlation between the AC transmission rate and resistance R5 and reactance Xc6*

Solution for banding

According to this model, solutions are as follows;

1. To increase the reactance of fuser heater and film, preventing the AC current leakage to the media.

2. To add the by-pass circuit from fusing film inside to the ground, preventing the AC current leakage to the media.

3. To add the by-pass circuit from Pressure Roller to the ground, preventing the AC current leakage to the media.

Conclusion

In SURF system, there is a possibility of horizontal banding image to occur, because SURF system has a fusing heater that is close to the fusing nip, and the AC current leakage is easily transmitted to the fusing nip and to a transfer area through the media, and oscillates transfer voltage. In this paper, we have simulated this banding by the RC circuit model between fuser and transfer area. The conclusions can be summarized as follows.

1. By the RC circuit model, we have simulated the banding level by the percentage of the AC transmission rate in transfer nip.

2. This percentage correlates to the banding level, and it's desirable to suppress this percentage within the 30% to prevent the banding to occur.

3. By the RC circuit model, we have found out the effective parameters and solutions for banding.

As mentioned above, banding can be controlled by designing a SURF system so that those solutions can be fulfilled.

References

[1] Kenichi Karino , Publication of a patent , JP2006-195003

Author Biography

Jun Asami received his MS in physics from Nagoya University, Japan in 2001. He joined Canon Inc. in 2001 and has been engaged in the development of electro-photography.

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