Characteristics of DC Charging Roller System

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Abstract

It is known that the mechanism of the charging roller system is the discharge generation in an air gap close to the nip region of the charging roller and the photoconductor. It is important to maintain the stability of discharge for the image quality. Generally, a charging roller has an elastic layer on the surface. The resistance of this elastic layer tends to change with environmental conditions or material property variations.

We focus on the fundamental composition that is DC bias charging roller system; the relationship between the resistance of the charging roller and the charged potential of the photoconductor are studied. Consequently, it turns out that the change of electrification potential and generation of uneven electrification are closely related to the resistance of a charging roller. Furthermore, it turns out that uneven electrification is generated due to condition changes which electric discharge is generated at an outlet region of the nip. We found that the above phenomena can be explained by using the relationship between passing time of the air gap close to nip area and the time constant of the roller resistance. From these results, the knowledge for stabilizing image quality is obtained.

Introduction

The charging roller system is the charging method that can make a miniaturization easily. Therefore, in recent years, it is widely used for the small machine and the color machine for office use. It is known that the electric discharge of an air gap formed close to the roller contact area is the dominant component in a mechanism of electric charge movement from the charging roller to the photoconductor.[1,2] It was presupposed that this air gap electric discharge was based on a Paschen's rule; the charging roller system has been variously examined using this principle.[1,2] Change of the air gap electric discharge causes change of electrification potential and uneven electrification. Especially uneven electrification has influence to the image quality. In the past, the charging roller system with DC bias has reported as more unstable system than system with AC+DC bias.[1,2] Moreover, there are examples of research that reported the uneven electrification in charging roller system with DC bias using the metal roller.[3,4] On contrary, there is a research that reported the stable electrification using DC bias charging roller system.[5]

We clarified of the generating conditions of uneven electrification and change of electrification potential in charging roller system with DC bias. Specifically, we have investigated the mechanism of direct-current bias contact electrification system using numerical analysis and experiment focusing on relationship between charging roller resistance and surface potential of a photo conductor. As a result, change of electrification potential and the factors of uneven electrification were traced the conditions of charging roller system with DC bias were clarified.

Theory

As the pointed out before, electric charge movement from the charging roller to the photoconductor (here after called OPC) is caused by the Paschen's electric discharge generated in gap close to the nip. We have especially considered the electric charge movement in air gap close to the nip. The contact region of a charging roller and an OPC consists of three portions: the nip region, the inlet region of nip, and the outlet region of nip; Fig. 1 describes those three regions.

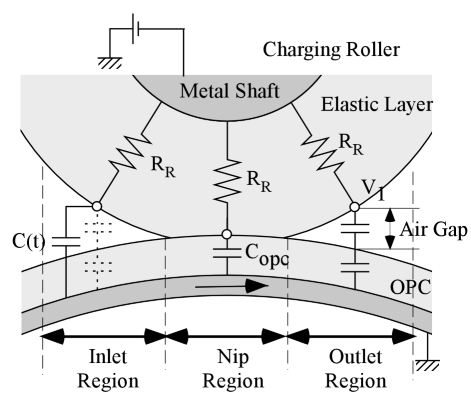

Figure 1. Schematic Diagram of Charging Roller Nip Regions

Due to the displacement of the OPC, the air gap in the inlet and the outlet region changes and thus capacity changes. If the capacity changes, the potential of the charging roller surface changes and the potential difference generated in air gap will also change; leading that the control of the surface potential by the voltage applied to the charging roller will become difficult.

In order to stabilize roller surface potential V_1 due to the change of the synthetic capacity C (t) of a OPC and the air gap, it is required to make roller surface electric charge Q (t) to follow the change of C (t) to maintain C=Q/V relationship. If time differentiation of this Q (t) is carried out, it will be set to current I (t) that flow through the resistance layer of a roller; the following equation will be obtained.

$$dQ(t)/dt = I(t) = V_1 \times dC(t)/dt \quad (1)$$

If V-V_1 is 10V and supposing that it is a permissible change, the following equation can be set.

$$I(t) \times R_R < 10\ [V] \quad (2)$$

The above equation assumes the potential stability of the roller surface in the inlet region and outlet region. If the resistance is larger than this value, electric charge will be unable to follow the change of C (t), and instead, V_1 will change.

Next, electric charge movement on the roller surface inside the nip region is considered. Since there is no air gap in the nip region, capacity is fixed to be as OPC capacity. Therefore, the relationship between time constant, obtained from the resistance of a charging roller and the capacity of a OPC; and the nip region passing time becomes:

$$\tau = C_{opc} \times R_R < \text{nip region passing time} \quad (3)$$

In other words, there will be enough time for electric charge to transfer from charging roller to the OPC during the nip passing time.

Therefore, it is clear that the change of OPC surface potential is closely related to the Eq. (2) and (3). In order to clarify this, the experiment and the numerical analysis are performed.

Experiment

The schematic diagram showing the experimental apparatus is shown in Fig. 2. The image developed on the OPC is to a middle transfer belt, then transfers to a paper. Surrounding the OPC belt, there are: charging roller, the developing unit, the erasing lamp, and the cleaning blade are arranged. The charging roller consists a metal shaft and the semi-conductive rubber layer.

Using above experimental apparatus, we measured the OPC surface potential and obtained the output image.

The resistance of the charging roller is calculated by using: the contact area between pressurized roller and a metal plate, and a current value 30 seconds after voltage applied.

The parameter of each part is as follows. (Process speed = 0.2[m/s], Diameter of charging roller/Backside roller of OPC belt = $11\times10^{-3}/30\times10^{-3}$[m], Charging roller pressure = 0.5[N])

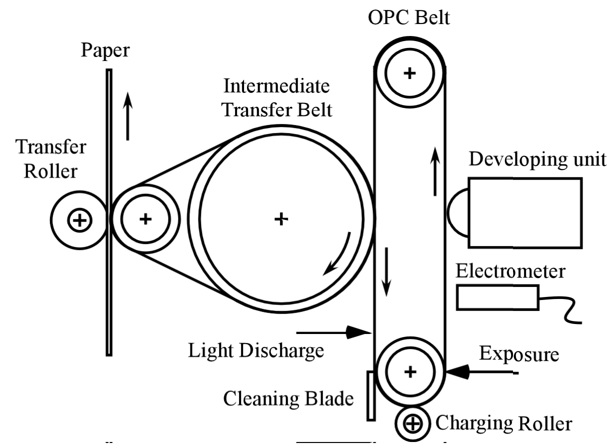

Figure 2. Schematic Diagram of the Experimental Apparatus

Calculation Model

It is necessary to consider: change of the rubber layer resistance, electric charge movement, electric charge movement by electric discharge, and air gap of the inlet and outlet regions in order to evaluate the electrification characteristic of the OPC using the charging roller. In this report, the model as shown in Fig. 3 is formulated. In this model, the amount of electric charge movements on the surface of an OPC is calculated separately in the following processes.

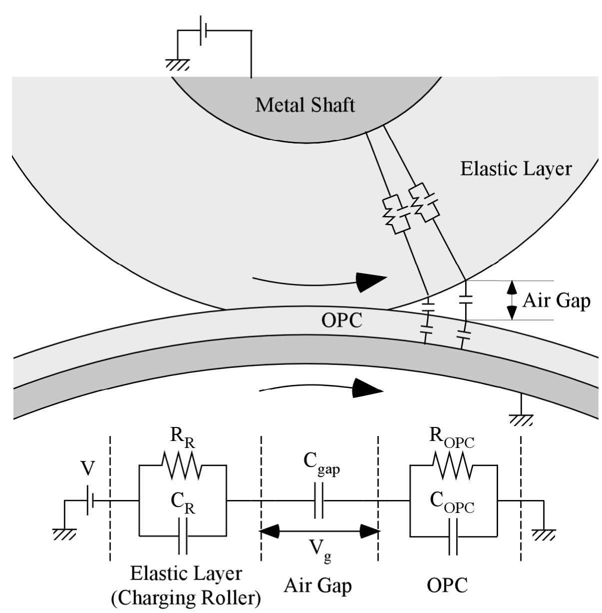

Figure 3. Calculation Model

a) Potential Distribution Calculation

A potential distribution in a minute domain is calculated. In this case, the potential of each part is calculated using a one dimensional circuit model consists a charging roller, air gap, and an OPC.

b) Calculation of Electric Charge Transfer Due to Discharging in the Air Gap Region

If the potential difference Vg in the air gap becomes larger than the voltage calculated in a), the electric charge of positive/negative will be given to a OPC and charging roller surface so that it may become smaller than the voltage calculated in a).[1,6]

$$V_g=312+6.2d \tag{4}$$

c) Calculation of Electric Charge Among Each Layer

The potential difference and the resistance between each point of contact are calculated, and the potential of each point of contact is rectified.

d) Moving Process

Iterative calculation using above calculation.

e) Iterative Calculation Using Above Calculation a)-c) During the Time Calculated by the Displacement Velocity and the Point-to-Point Distance

The potential and electric charge density of each point of contact (node) are obtained by iterative calculation from an upper stream node to a down stream node.

The parameter of each part is as follows. (Thickness of elastic layer/OPC = $5.5 \times 10^{-3}/20 \times 10^{-6}$[m], Dielectric constant of elastic layer/OPC = 5.5/3, Volume resistance of OPC = 1.0×10^{15}[Ωcm], Width of nip = 0.56×10^{-3}[m])

Results and Discussion

The values of R_R calculated using Eq. (2) and Eq. (3) are shown in Table 1. It is expected in these resistances R_R that behavior of OPC surface potential changes.

Table 1. The Calculation Value of R_R

Nip inlet/outlet region (from Eq. (2))	9.1×10^5 [Ωcm]
Nip region (from Eq. (3))	3.8×10^7 [Ωcm]

Figure 4 shows the experimental and calculated results of the relationship between the volume resistance of a charging roller and the OPC surface potential.

Although the OPC surface potential shows the stability when volume resistance of a roller is below 1×10^6 Ω cm, the potential increases rapidly as the resistance increases in both experiment and calculation results. The peak of the potential is at 3×10^7 Ω cm then rapidly drops as the resistance increases.

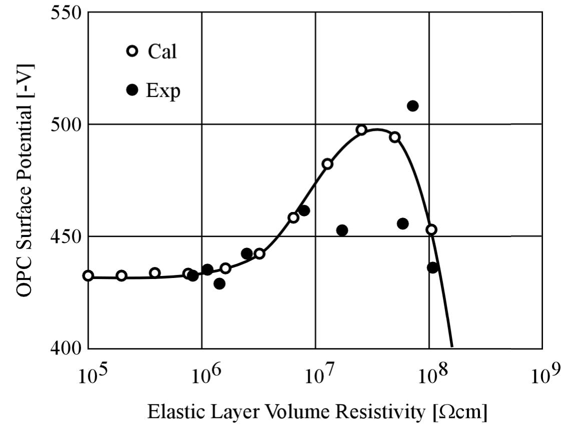

Figure 4. Relationships between OPC Surface Potential and Elastic Layer Volume Resistance. (V=-1000[V])

Figure 5 shows the calculated results when the resistance is 1×10^6Ω cm. The center of the graph represents the center of the nip region. Since this case consists Eq. (2) relationship, the potential is relatively stable due to charging roller surface potential becomes nearly equal to the metal shaft potential.

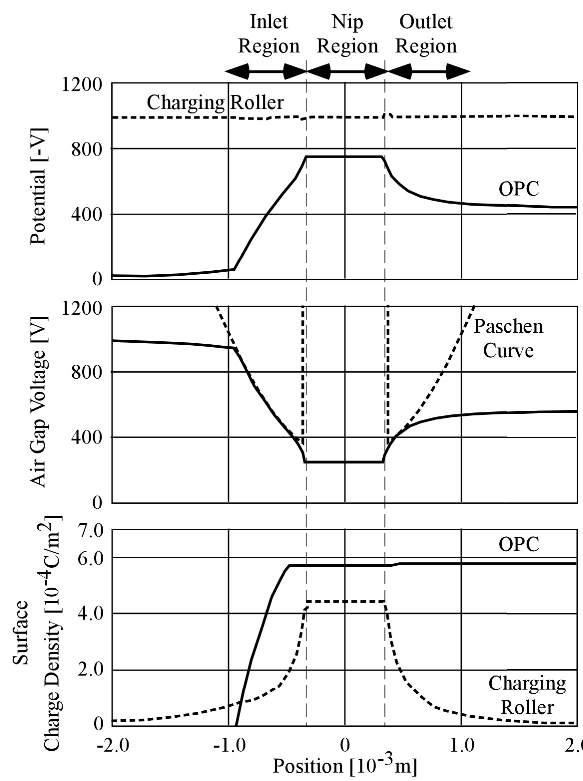

Figure 5. Distribution of Potential, Air Gap Voltage and Surface Charge Density. (V=-1000[V], $R_R=1 \times 10^6$[Ωcm])

This is because fair amount of discharging occurs in the nip inlet region and not in outlet region.

Figure 6 shows the calculated results when the resistance is $5 \times 10^7 \Omega$ cm. Since this case has higher resistance than the previous case, the surface electric charge density becomes unstable due to the roller surface potential cannot follow the change of the capacity change in the nip inlet and outlet regions. In the nip inlet region, there are not enough discharge due to decrease in capacity and the decrease in roller surface potential.

However, in the nip region, roller surface potential changes until it balances the Eq. (3). At this moment, since there are small amount of charge transferring in the nip inlet region and the OPC surface potential is still low, the charge in the roller surface become larger than the previous case shown in Fig. 4. Therefore, at the nip outlet region, the large amount of discharge occur and thus potential becomes larger than the case where low resistance roller is used. This is reason why potential rises as the resistance rises.

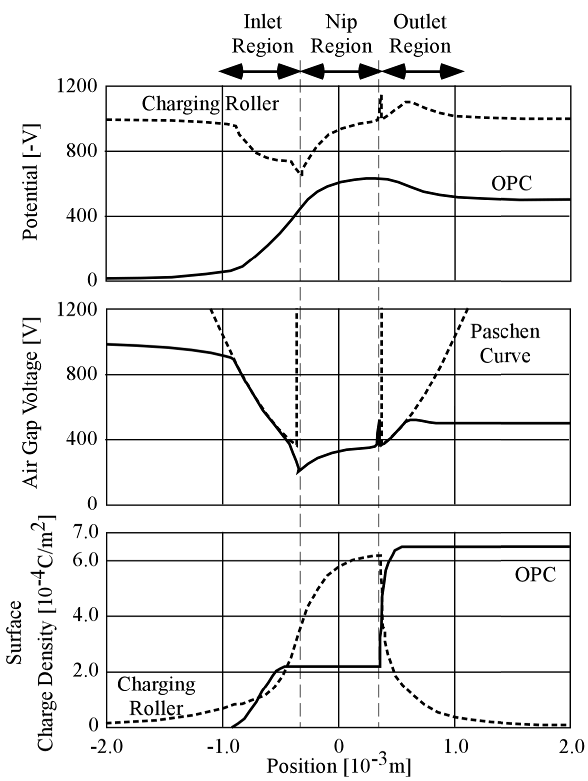

Figure 6. Distribution of Potential, Air Gap Voltage and Surface Charge Density.(V=-1000[V], R_R=5 $\times 10^7$[Ωcm])

Furthermore, in this condition that the roller surface potential cannot follow the change of the capacity change, the amount of discharge is highly sensitive to the change of the air gap. This shows that change of the spread speed of air gap by a mechanical vibration and modification of a roller generates uneven electrification. The image in Fig. 7 shows the output image of using $5 \times 10^7 \Omega$ cm roller. The image has horizontal white streak due to the dominative discharging in the nip outlet region.

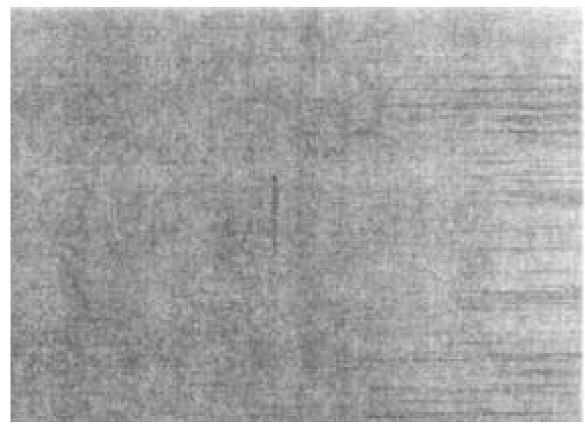

Figure 7. Image of Streaks

In order to compromise uneven electrification using the high resistance roller, it is necessary to mechanically stabilize a roller pressure or optimize the roller surface layer elastic modulus.

Conclusion

We clarified the mechanism of the generating conditions of uneven electrification and change of electrification potential in charging roller system with DC bias for stabilizing of image quality. The change of electrification potential and uneven electrification are strongly influenced by the resistance of the charging roller because its resistance determines charging location and amount of charges during discharge. Especially in the nip outlet region, the capacity decreases rapidly makes difficult to transfer charge, and makes difficult to follow such capacity change; consequently discharge becomes dominative in the nip outlet region. Therefore, discharging process becomes sensitive to the nip outlet region geometry that can be easily changed by vibration or other components.

From the above results, charging roller system with DC bias technology without uneven electrification was established by optimizing resistance.

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Biography

Masashi Yamamoto received his B.S., and M.S., degrees in Niigata University, Japan (Engineering Department, Electronic course in 1989 and 1991, respectively. In 1991, he joined Hitachi, LTD in Japan. Since 2003, he has worked in Hitachi printing Solutions, LTD. His current research area is charge and transfer process.