Wave Image Artifacts in Monocomponent Development System

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Abstract

The wave artifacts phenomenon is from uneven imaging on the media. This is more noticeable in low relative humidity conditions (less than 15%RH). Experimentally, these phenomena are caused by the developer roller surface condition and the chargeblade condition. These are the two critical components for correct toner development. The function of the developer roller is toner tribo-charging and to supply charged toner to the photoreceptor for image development. The developer roller requires the correct surface roughness and electrical resistance. Low surface roughness of the developer roller causes the wave image. Also, the chargeblade force contributes to this phenomenon.

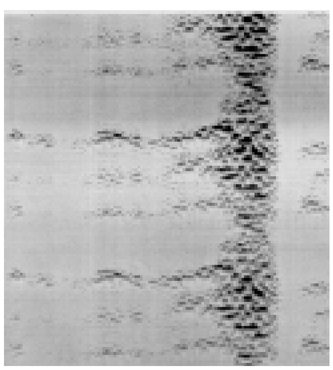

Figure 1. Wave Image

Introduction

The wave artifacts are sometimes called wave image, wavy background, marbling or tire tracking patterns. This report will use the term wave image. An example of the wave image is shown in Figure 1. These patterns most often show up in 40% grayscale. The unevenness of image density in the 40% grayscale appears as a wave on the page. A worn development roller or a worn chargeblade are well known causes of these patterns. This report analyzes, (1) what is the effect of the developer roller surface conditions, (2) what is the effect of the chargeblade condition and (3) why the 40% grayscale shows the wave image so strongly. By experiment, the wave image can be eliminated by changes in the component conditions.

Experiment

The experimental printer's process speed was 12 page per minutes and 600 dpi resolution. The toner was 8 μm average by volume measurements and monocomponent magnetic type toner. The imaging components are shown in Figure 2. The organic photoconductor's outer diameter is 30 mm and charged by a primary charge roller (PCR). The developer roller outer diameter is 16 mm. The developer roller and photoconductor don't contact and the gap is 300 μm. The development system is toner projection development, usually known as "jumping" development.

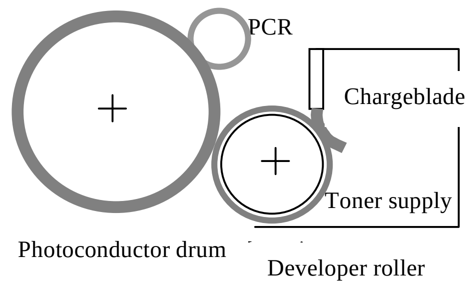

Figure 2. Schematic of the development components

The wave image can be erased by using the right condition components. The chargeblade changes the toner layer thickness on the developer roller. This has been discussed in detail by Schein[1] and others. The developer roller surface condition controls the toner charge and toner layer thickness.

The difference is 0.2 O.D.U. (Optical Density Unit) between the 40% grayscale image and the wave image. The average image density of 40% grayscale is nearly 0.2 O.D.U. and the wave image is 0.4 O.D.U.

The effect of the two critical components is shown in the Tables below, and previously by Dreyfuss[2]. Table 1 shows that the thickness of the toner layer controls the image density level, i.e. light or dark. A low toner charge makes high image density with a low force chargeblade. The low roughness developer roller has low image density. The low toner charge makes the high image density which means a dark image. From these Tables, if the components used are the low force chargeblade and the high roughness developer roller the image density is darker than usual. The actual developed image has been analyzed and the relation between toner layer and image density will be calculated next.

Table 1. The toner layer by the components

	Low	High
Chargeblade force	Thick	Thin
Developer roller roughness	Thin	Thick

Table 2. The toner charging by the components

	Low	High
Chargeblade force	Low	High
Developer roller roughness	High	Low

Table 3. The image density

Image density	Low	High
Toner layer	Thin	Thick
Toner charging	High	Low

Analysis

The wave image is from unevenness in the developed toner. This is the reason it is noticeable on the 40% grayscale page.

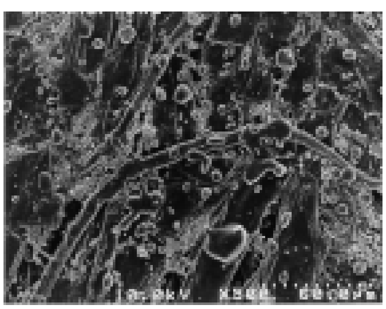

Figure 3. SEM photo of 40% grayscale normal image

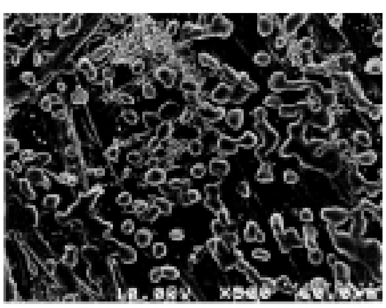

Figure 4. SEM photo of wave image area of 40% grayscale

Figure 3 is a photo of the regular halftone image taken by SEM (Scanning Electron Microscope). The difference between Figure 3 and Figure 4 is the toner amount on the media. By these SEM photos, it can be seen that the phenomenon of the wave image is caused by the toner amount developed.

The development forces are calculated below.

The forces on the toner are the electric force due to the electrostatic image (Fe), electric force due to the triboelectric charge on the toner layer (Ft), the magnetic restrictice force (Fm), gravity (Fg) and the physical adhesion force (Ff). The total force that makes toner movement is

$$F(Y) = Fe + Ft + Fm + Fg + Ff \quad (1)$$

This has been discussed in Takahashi's report[3] in detail. The toner starts to develop when the condition is

$$F(Y) \geq 0 \quad (2)$$

Y is the distance from the developer roller surface (Y=0 at the roller surface) as shown Figure 5.

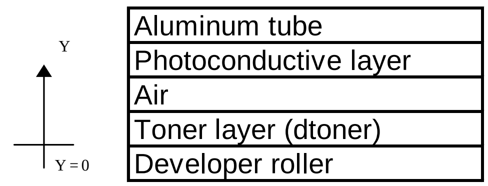

Figure 5. Schematic of the development point

For the start of development, the toner requires that

$$Y > Y_{F=0} \quad (3)$$

$$d_{toner} > Y > 0 \quad (4)$$

Then image density is,

$$D = D_{max}\,(d_{toner} - Y_{F=0})/d_{toner} \quad (5)$$

D is the image density and D_{max} is highest image density (D_{max} = 1.40 O.D.U. for these calculations).

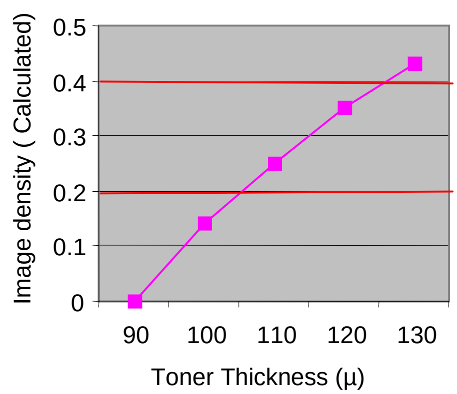

Figure 6. The difference of the image density by the toner layer

From Figure 6 it can be understood that a toner layer difference of 10 μm makes a big difference in image density in the grayscale area. Of course there is a difference on the black solid page but to the human eye, there is not such a big difference between 1.40 O.D.U. and 1.45 O.D.U. The grayscale page has 0.2 O.D.U. and the wave image has 0.4 O.D.U. as measured. By this calculation, it is shown that the wave area is about 10 µm thicker than the regular developed area. Ten µm is about the same as one toner particle size. So, these results have found that one toner layer difference in the grayscale image makes the image density uneven.

What about in the white image and black solid image? The calculated data of the white page area and the black page area are shown in Figure 7 and Figure 8, respectively.

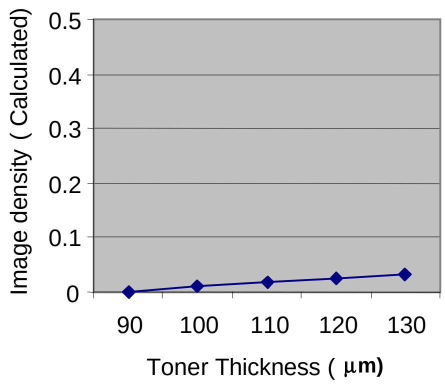

Figure 7. The difference of the image density by the toner layer on white page

For the white page the difference between the toner layer thickness results in a density difference of only is 0.03 O.D.U. by calculation. The wave image does not appear on the white page in these experiments.

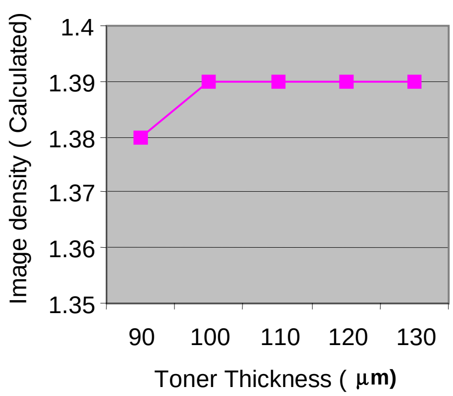

Figure 8. The difference of the image density by the toner layer on black page

For the black page there is no big difference in the image density when changing the toner layer thickness. The difference is about 0.01 O.D.U. This agrees with the experiments where no wave image was seen in the black page. The wave image is unique to the grayscale pages.

Toner Particle Size Effects

It's also thought that toner particle size has an effect on this phenomenon. By the SEM photos, it has not been confirmed that size selection is involved. Of course, the particle size distribution is important but for this discussion the assumption has been that the same range of particle sizes are developed. By rough calculations, the smaller toner particles should make the wave image appear more than the larger size particles. This is because the small particle size toner has a higher average charge[4].

Humidity Effects

The effect of low humidity[5] is to make lower print density, usually (with these type of EP systems). This makes the wave image more noticeable. That is because the toner has been charged higher and the grayscale page has a lower density than usual and the wave image shows up by the toner layer unevenness.

AC Bias Effects

"Jumping" development uses an AC bias on the developer roller. The AC bias effect has been calculated and the DC component was effective in the control of image density, as shown by Takahashi et al. Usually, the AC bias effect is clear background and well defined edges. In these experiments the test condition was the same between the usual image and the wave image. Therefore, this has not been discussed at this time.

Conclusion

The wave image has been caused by the critical development component condition. In particular, the developer roller and the chargeblade which control the toner layer thickness need to keep it uniform throughout the development process. This result has been shown by calculation, also.

References

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Biography

Tadahiro Kaneko received his M.S. degree in Physics from the University of Ibaraki at Mito Japan in 1992. From 1992 to 1996 he had worked in the Katsuta Laboratory for Research and Development for laser printer at Hitachi Koki Co., Ltd. in Japan. Since 1996 he has worked in imaging product development for laser toner cartridges at Dataproducts Corporation whose name has been changed to Hitachi Koki Imaging Solutions, Inc. from April 1999. He has focused on the development process components including imaging materials and image quality issues. He is a member of the IS&T.