The Influence of Toner and Paper Properties on Electrophotographic Print Quality

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Abstract

The print quality of a high speed electrophotographic process was evaluated using toners with different particle diameter distributions and papers with different roughness, thickness, and electrical conductivity. Additionally the fusing conditions were varied.

The influence of paper properties on halftone image quality was examined. A new equation describing the relationship between per cent dot area and optical density of screened areas considering the light scattering in the paper was derived and proved by experimental evidence.

The results lead to conclusions regarding reasonable relationships of print resolution, requested toner properties and reasonable paper quality parameters.

Introduction

In the last years the print quality level of electrophotographic printers was significantly improved by introducing higher resolutions up to 600 dpi and special edge smoothing techniques. The higher print quality requests finer toners and better paper qualities. Additionally the fusing process influences the print quality. To realize reproducible gray levels in halftone printing the knowledge of the relationship between the per cent dot area and optical density of screened areas for different papers is necessary. The aim of the analysis presented in this paper is to get data about the requests that have to be fulfilled by the toner, the paper and the dot screen shaping for high quality printing of characters, line graphics and halftone images.

Line Print Quality

The print quality of lines and characters is defined by the optical density profile of fine lines and characters, the line uniformity, the line sharpness and by the gloss. Especially the line sharpness is strongly influenced by the toner and paper properties. As a quantitative measure of the line sharpness the edge raggedness (after J.R. Hamerly[1]) is used.

Figure 1 shows the results of edge definition measurements made on papers with different roughness using toners with different diameter distributions. Finer toners exhibit a better edge definition compared to more coarse toners. The paper roughness is practically without influence on the edge definition until paper roughness of about 200 ml/min. Beyond 200 ml/min the edge raggedness raises steeply with increasing paper roughness

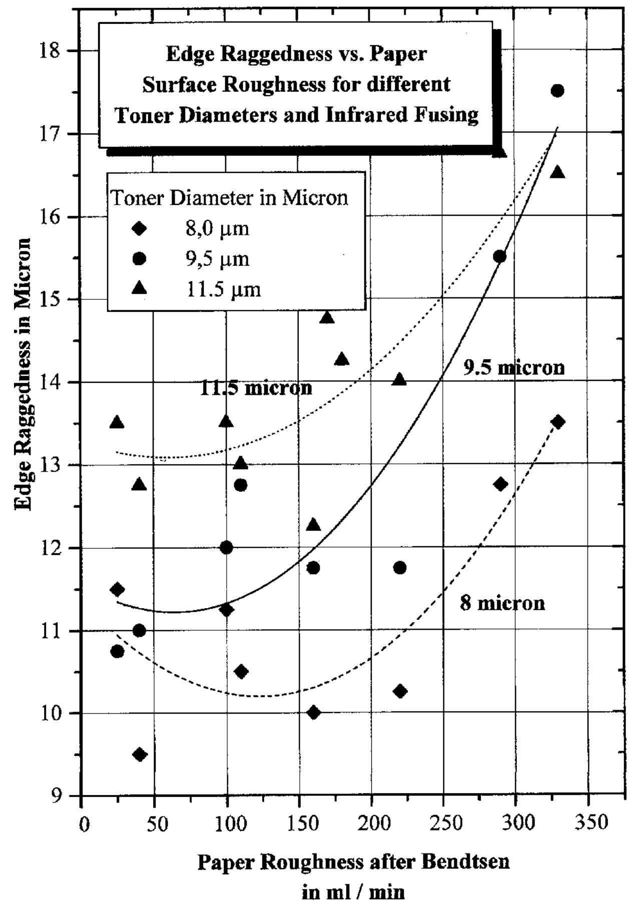

Figure 1. Edge raggedness versus paper surface roughness for different toner diameters.

In Figure 2 the edge definition is plotted in dependence of paper roughness for different fusing techniques. The contact free heat fusing leads to the highest edge raggedness. Heat roller fusing shows similar results regarding the edge definition for hard fuser rollers and soft fuses rollers respectively. The lower raggedness of the heat roller fused images is caused by the pressure, which connects neighboring toner particles.

Optical Density of Halftone Areas

Without considering the light scattering in the paper, the relationship between the per cent dot area φ, the maximum optical density of a completely toner covered area D_T and the integral optical density of the halftone area D_R is described by the well known Murray-Davis equation[2]:

$$D_R = -\lg\left[1 - \varphi(10^{-D_T})\right]. \quad (1)$$

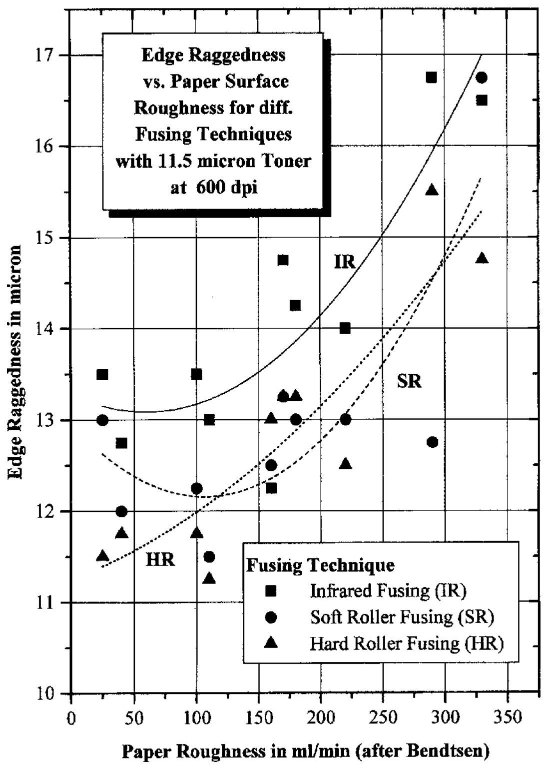

Figure 2. Edge raggedness versus paper surface roughness for different fusing techniques.

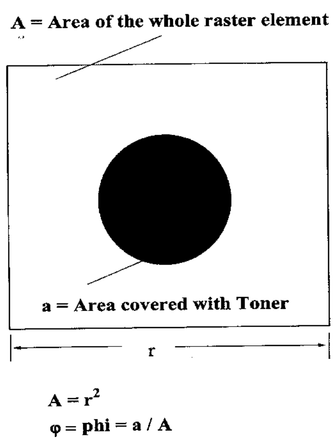

Figure 3. Schematic of the raster pixel areas.

Taking into consideration the light scattering, the light energy H_R remitted from the raster pixel area **A** is described by equation (2):

$$H_R = H_W\,(1-\varphi) + H_T\,\varphi. \quad (2)$$

H_W (1– φ) is the light energy remitted from the toner free area (**A –a**). H_T φ is the light energy reflected from the toner surface area **a**.

H_W consists of two components:

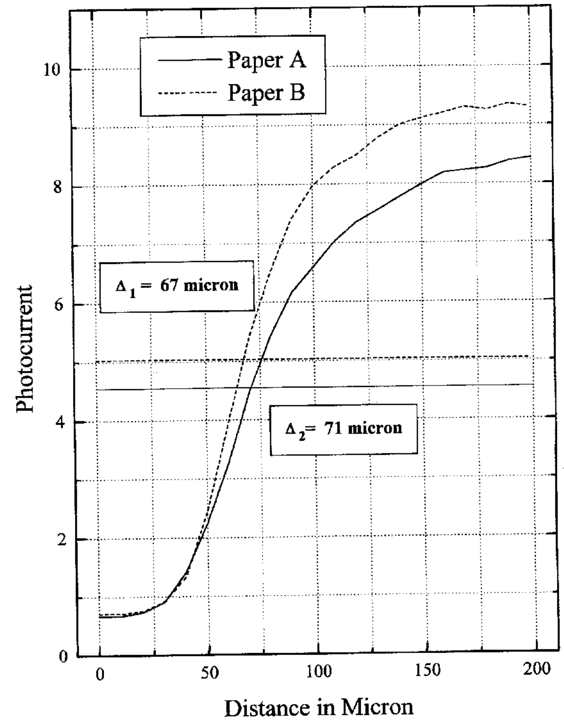

Figure 4. Light scattering functions for two papers, Δ = half-width of the raising light scattering function.

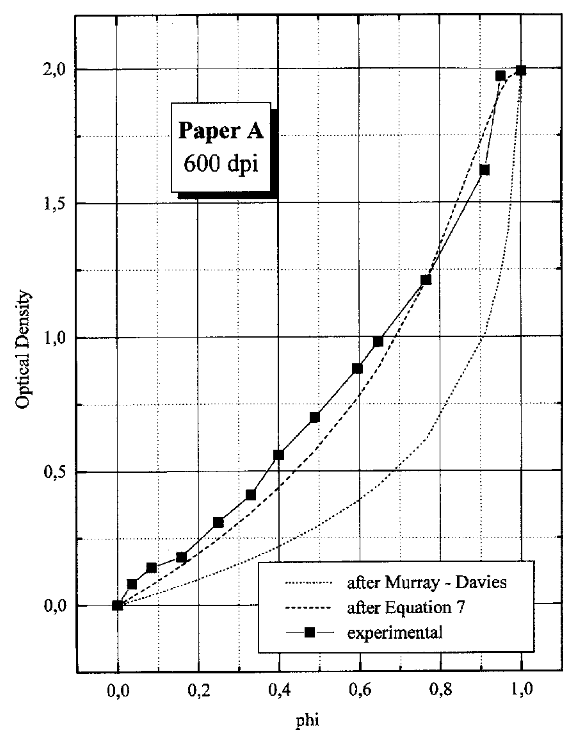

Figure 5. Optical density of halftone areas in dependence of the percent dot Area σ for 600 dpi screens on paper A.

$$H_W = H_{PS} + H_{PV}. \quad (3)$$

H_{PS} is the light energy that is reflected directly at the paper surface. H_{PV} is the light energy that is remitted from the toner free areas after scattering in the paper volume.

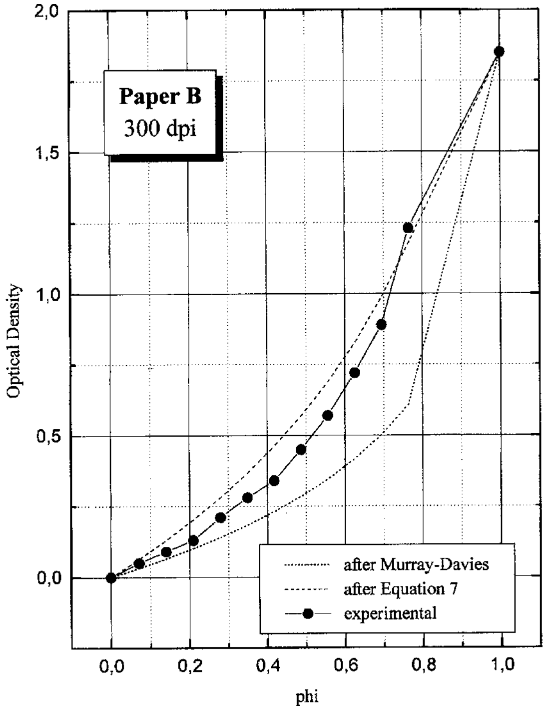

Figure 6. Optical density of halftone areas in dependence of the percent dot area φ for 300 dpi screens on paper B.

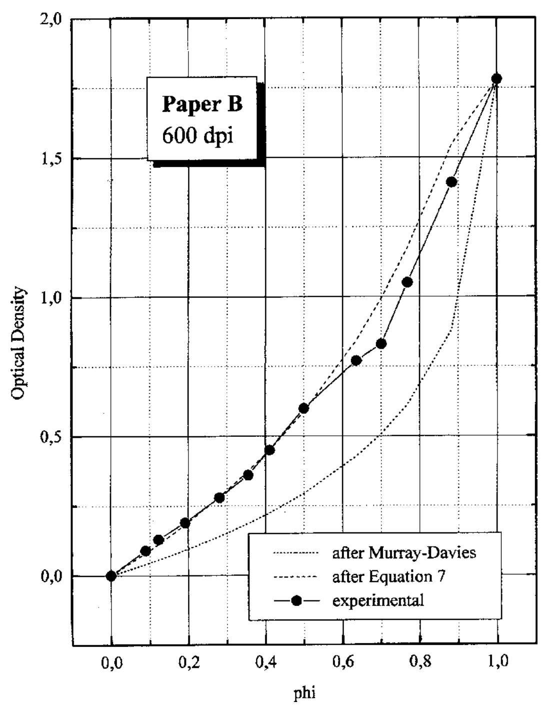

Figure 7. Optical density of halftone areas in dependence of the percent dot area φ for 600 dpi screens on paper B.

At the rear side of the toner covered area **a** the light scattered in the paper volume will be absorbed. The amount of the absorbed light increases with broader light scattering function of the paper.

An evident border-line case for the light scattering process in the paper is: the light reflection directly from the paper surface is negligible ($H_{PS} << H_{PV}$) and the light scattering in the paper volume is very strong and uniform: Δ >> **r**. That means that all light that enters the paper surface (**A – a**) is uniformly distributed in the paper volume. The light which contacts the rear side of the toned area a will be absorbed. The emerging light energy per area decreases by the factor (A – a) / A = (1 – φ). For toner free paper the light energy emitted from the paper surface H_W has its maximum value H_O.

With $H_{PS} = 0$ and $H_{PV} = H_O (1 - \varphi)$ equation (3) changes into

$$H_W = H_O (1 - \varphi). \qquad (4)$$

Replacing H_W in equation (2) by (4) leads to

$$H_R = H_O (1 - \varphi)^2 + H_T \varphi. \qquad (6)$$

The optical density D_R of a halftone area with a percent dot area φ and a maximum toner density D_T for negligible direct light reflection at the paper surface and uniform scattered light in the paper volume is:

$$D_R = -\lg\left[(1-\varphi)^2 + 10^{-D_T}\varphi\right]. \qquad (7)$$

The equation (7) exhibits a good fit of the experimental data in the Figures 5, 6 and 7. The Murray-Davies curves are not suitable to fit the experimental figures in the limits of the experimental errors.

The differences of the relative positions between the equation (7) curves and experimental data of Figure 5 and Figure 6 are caused by the different light scattering functions of the papers B and A (see Figure 4). The broader light scattering function of paper A leads to higher light absorption in the paper—not yet considered by equation (7).

Finer raster pixels for 600 dpi exhibit higher optical densities for the same φ-values compared to the coarser 300 dpi pixels because of better approximation of the condition Δ >> **r**.

Summary

The paper roughness is practically of low influence on the edge definition of 600 dpi lines until paper roughness of about 200 ml/min. Beyond 200 ml/min the edge raggedness raises steeply with increasing paper roughness. The edge definition improves almost linearly with decreasing toner particle diameters.

The fusing conditions influence the edge definition in significant manner.

The derived equation (7) provides a good approach of the optical density versus per cent dot area of electrophotographic printed halftones.

Acknowledgment

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References

1. J. R. Hamerly, An analysis of edge raggedness and blur, *J. Appl. Photog. Eng.* **7**(6), 148-151 (1981).
2. A. Murray, *J. Franklin Inst.* **221**(1936) 721.