

# Measuring Cleaning Performance in an Electrophotographic Process

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## Abstract

A technique to measure cleaning performance, using particle counting, in an electrophotographic process is reviewed. Steps to transform a post cleaning area tape sample into a visual, image while minimizing external noise factors, are outlined. Once presented to the image analyzer, examples of samples manipulated to enhance the residual toner particles using a high gauss filter are illustrated. The number of particle counts needed for each sample to provide some type of statistical significance is discussed. This is followed by an explanation of how these components were integrated into a short computer program to further minimize amount of time the measurement involves. The final element of this technique, correlating the collected data to cleaning performance, is examined considering both its benefits and limitations as a measurement tool.

## Introduction

Image artifacts causing poor image quality are a major source of concern in electrophotography. A build-up of toner particles, which have been missed by the cleaning station on the photoreceptor or other surface, can cause a myriad of problems from black spots that appear on a final copy to contamination and eventual failure of other subsystems within the process. Even if transfer efficiency was 100% other materials, such as paper dust and carrier particles, are resident on the surface and must be removed. In order to estimate the efficiency of the system it is necessary to measure any residue the cleaning station has left behind.

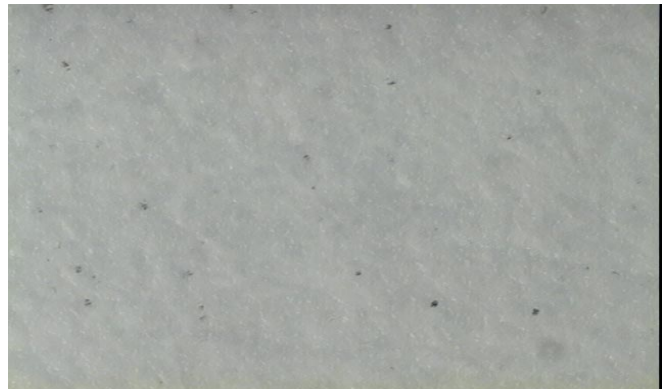
## Sample Preparation

Toner remaining on a surface after cleaning is collected via "tape samples." The machine is abruptly stopped and cellophane tape is then applied to the surface of interest with light pressure so that the adhesive captures all the toner particles on the surface when the tape is gently peeled off.

Prior research found 3M tape No. 810, Magic Tape, was favorable for this application because it has less propensity to remove unwanted material like the film

emulsion. The usual practice was to apply the tape to clean white paper for examination.

The first problem with this technique is that it requires viewing the particles through the tape. This results in an index of refraction mismatch so that the particles themselves look distorted. Viewing must also be done through or around the glue that is under the tape adding to the distortion and creating additional shadows and "phantom" particles. A sample image is shown in Fig. 1.



*Figure 1. Photomicrograph of particles using original collection technique.*

Steps to improve the image to be analyzed included replacing the clean white paper with pre-cleaned gold seal microscope slides No. 3010 as the receiver medium. This allowed viewing of the particles through the slide rather than through the tape removing the issues around index of refraction mismatch. The next step was to place a piece of white photographic paper underneath the viewing area. This eliminated the roughness previously associated with bond paper that created unwanted shadows in the sample window. Replacing 3M No. 810 with No. 600, Transparent Tape, improved the technique because like No. 810 it also does not remove unwanted material, but it also does not possess the flat matte finish, which added unwanted noise to the background. Reflective light in the form of a ring light was used to brighten the area of interest and minimize any remaining shadows. A live representation of the microscope image is available using Image-Pro integrated

software for the capture and analysis of the area of interest. This program allows the user additional brightness and contrast controls to fine-tune the image appearing on the screen. A sample of a final captured image is shown in Fig. 2.

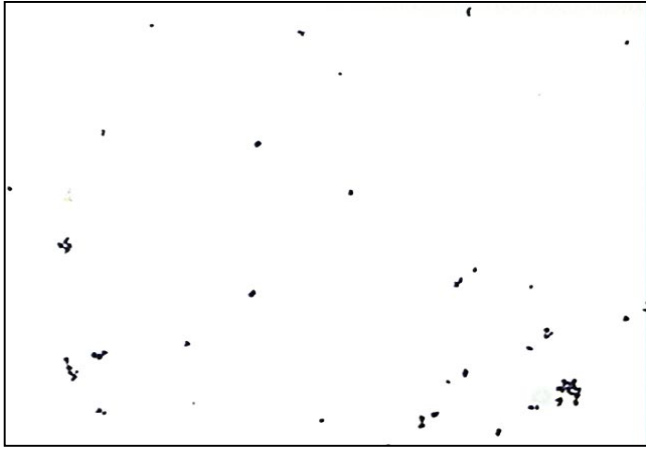


Figure 2. Photomicrograph of particles using improved collection technique.

### Sample Analysis

Once the user is satisfied with the captured image presented to Image-Pro it is time to perform the analysis. The computer is calibrated using a 1 mm scale to make measurements using the microscope and a 5X objective. The measurements made include a count of the particles observed and a measurement of the percent of the total area covered by the particles. Any objects that intersect the edges of the image are excluded from the count and measurement calculations using an option called "clean border."<sup>1</sup> A high guass filter using a 7 x 7 kernel size is applied to the image. This filter is used to enhance fine details similar to the technique used in a sharpening filter, but it introduces less noise in the process. It uses a Gaussian curve type of kernel. A kernel refers to a cluster of pixels being filtered, with a large kernel producing a more extreme filtering effect. In plain terms, this filter provides added definition to the edges of the particles in the image making them easier for the program to distinguish and measure. A sample of an image after the application of the high guass filter is shown in Fig. 3.

Before counting the particles within the image it is necessary to select intensity range values that define the objects to be counted and measured. This option is essential when working with both a color camera and various toners. Once the intensities are determined the image can be counted. The number of particles observed by the computer and their appropriate measurements are calculated and can be stored in Microsoft Excel software. Image-Pro provides a built in language called Auto-Pro<sup>2</sup> which allows the user

to record their preferences and generates a program which will execute the steps required for the analysis of any future images.

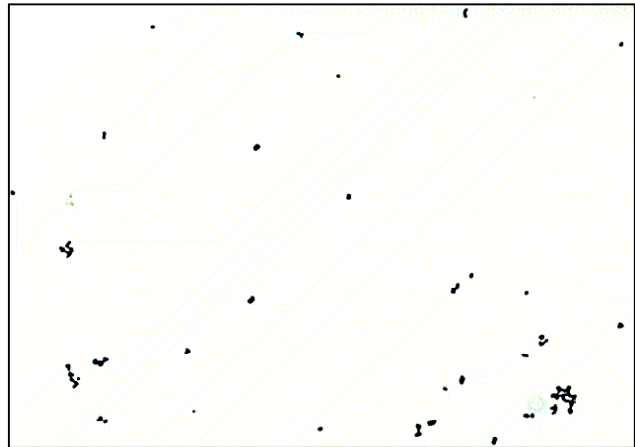


Figure 3. Photomicrograph of particles enhanced using high guass filter.

### Discussion

The one major drawback that still exists with this technique is sampling. A tape sample represents only a portion of the surface being cleaned and therefore only captures a sample of the population of toner particles lying on that surface. From each tape sample less than two dozen images are currently examined so that the fraction of the original population being sampled is incredibly small. Yet the numbers generated are taken as a measurement of the cleanliness of a given surface.

Two problems exist that prohibit sampling a large percentage of the population. First, given the size of each image taken from a tape sample, approximately 1.2 mm,<sup>2</sup> the number of individual images that would have to be analyzed to greatly increase the population being sampled would be time consuming. Second, this number of images may not greatly increase the confidence level, since a single tape sample is still only sampling a portion of the surface. A solution to the first portion of the problem might be attained with the addition of an automated stage. This would allow the user to set up the system to automatically map an entire tape sample and collect the needed data and thereby allow more tape samples to be taken and examined at a given set of test conditions.

More investigation into the merits of this approach is needed. Currently, the measurements obtained from this technique are not touted as absolute values, but rather they are used as a relative metric. In experimentation, this technique is fairly effective for predicting trends, whether one set of cleaning parameters results in a cleaner surface than another. Reviewed in this context, the discussion becomes whether increasing the confidence level in the

absolute value of the measurement is necessary. This particular discussion requires more debate and investigation before an accord will be reached.

### **Conclusions**

In conclusion, the first step to accurately counting particles is to present a superior image to the analyzer. This has been achieved through a series of steps designed to eliminate noise that was originally accepted. Beyond this, improved computer aided programs allow further enhancement of the images and provide data that was just a short time ago not accessible. Finally, along with increased access to larger volumes of data it must be determined how much information is just enough.

### **References**

1. Media Cybernetics, Image-Pro Plus Reference Guide for Windows, Media Cybernetics, Silver Spring, MD (1997).
2. Media Cybernetics, Auto-Pro Guide for Windows, Media Cybernetics, Silver Spring, MD (1997).

### **Biography**

Michelina Molongoski received her B.S. in Mechanical Engineering from the University of Notre Dame in 1988 and her M.S. in Material Science from Worcester Polytechnic Institute in 1990. Since joining Kodak's Office Imaging Division, now Heidelberg Digital, in 1996 she has performed research and development in the area of high volume electrophotographic cleaning and fusing subsystems. Prior to 1996 she conducted research in high performance ceramic materials at the Army Research Laboratories in Watertown, MA.

Jim Maher received his B.S. in Physics and an M.S. in Electrical Engineering from the University of Rochester in 1970 and 1980 respectively. He has been involved in advanced research and product development throughout his career.