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Dot Area, Dot Gain, and n-Factors

This abstract will covers the issue of dot area/dot gain readings, how to insure proper readings, and how to interpret the data collected. It covers a broad area of interests including press dot area, proof dot area, and film dot area.

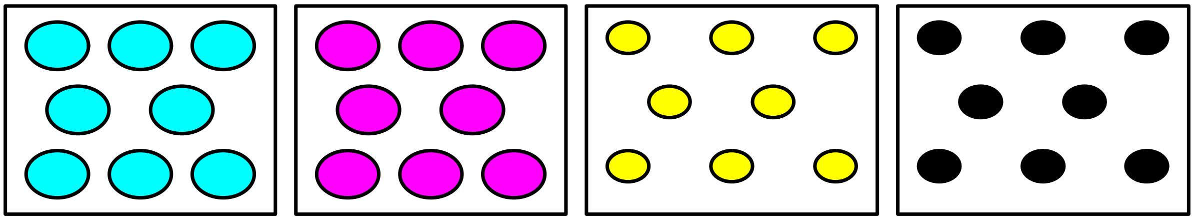
Why Dots ????

The printing process is a collection of other discrete processes all needed to produce the end product; typically an image on paper. In reproducing a full, or four-color image a photograph is separated into four components represented on film. One film is produced representing the amount of cyan found in the image, one for the amount of magenta, and one for the amount of yellow. A fourth film is produced which represents the black portion of the photograph which typically is wherever cyan, magenta, and yellow are all present in equal amounts. In order to simulate varying amounts of a given color found in a photograph, we use dots that change diameter or total coverage. For example, if we took one spot on a photograph and broke it down into its various components we may end up with something like this :

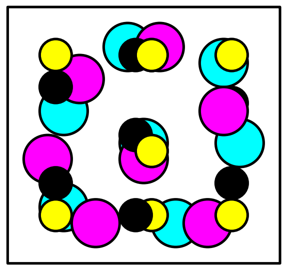
Black	=20 %
Cyan	=40 %
Magenta	=40 %
Yellow	=20 %

In order to reproduce this particular spot we will create films with these dot percentages, or halftones, and overlay them. Since we are using dots instead of a continuous tone method as represented in the original photograph, we have to trick our eyes and make these dots small enough so our eyes cannot notice what they actually are.

The individual components and overlay would look something like this :



Cyan = 40 %   Magenta = 40 %   Yellow = 20 %   Black = 20 %



Overlay

The overlay looks fairly peculiar here but if you were to make it small enough, the eye would see it as a single color. Hence the simulation of continuous tone photography.

As printers, one of our main concerns would be to control the size of the dots. It is essential that pressmen know when the dot is sharpening or growing. A 3% growth or decrease in the dot area in any or all components will be enough for our eyes to notice a change in the overall shade or hue of the reproduced image. Hence, measuring dot area and dot gain are crucial to the control of overall color.

Dot Area vs. Dot Gain

What are dot area and dot gain and how are they calculated? In simplistic terms, a dot area measurement is the ratio between the amount of light reflected back, or transmitted, through a given halftone versus the amount of light collected back from or through a solid of the same color. The common equation follows :

$$\frac{1 - 10^{-Dt}}{1 - 10^{-Ds}} \times 100$$

where:

Dt is the **density** of the **tint** or halftone
Ds is the **density** of the **solid**

Note : **Dt** and **Ds** are **always** measured **minus paper**

The preceeding equation is called Murray-Davies; named after the researchers who first proposed its use. Don't be bothered by the math. These equations are built into most modern digital densitometers. The main point of the math is that it compares two values, a tint, and a solid. As the tint gets darker (larger dots) and the solid stays the same, the overall number will be larger. Hence the computed dot values increases as the tint increases.

Dot gain is also a comparison. It is a comparison of the film dot area versus print sheet or proof dot area. It is calculated using the following formula :

% Dot Area Printed Dot - % Dot Area Film Dot

For an example if a measurement of 50% dot area is obtained from the film and a 67% dot area is obtained from a proof or press sheet then the corresponding dot gain is 17%.

Or...

67% - 50% = 17 %

At first glance, dot area and dot gain seem to be fairly straight forward concepts. Unfortunately, the concept of dot gain is more involved and requires further discussion. Dots, and their interaction with the substrate on which they are applied, become a complex issue. The growth of dots and the difference between film dot and paper dot is not simply governed by the pressure of blanket to paper. Dot gain can also occur in other parts of the printing process and in different ways. It can be broken down into two components; mechanical dot gain and optical dot gain.

Mechanical Dot Gain

Mechanical dot gain can be summed up as any *physical* growth or loss the dot experiences by things like gear play or over-exposure. Mechanical dot gain in turn is divided into two sub-groups: directional and non-directional.

Directional dot gain would be dot gain incurred through doubling or slurring. Slur is the deformation of a dot due to surface speed difference of two cylinders. The difference in speed causes the dot to elongate in the printing direction. Although often present, slur has no significant contribution to overall dot gain. It typically adds only 1% to 2% in the worst cases.

Doubling, on the other hand, can affect dot sizes more significantly. Doubling is basically a registration problem on multi-color presses. As an image passes from the first unit to the second unit, the image is transferred because the ink is still wet. If the impression of the first unit doesn't exactly match it's "shadow" on the second, then doubling occurs. This problem can have many causes such as paper stretch and gear play.

Non-directional mechanical dot gain is defined as dot gain incurred from other press related problems such as fill-in or improper exposure during the platemaking process. Fill- in can be the result of too much pressure. More times than not, however, it is caused by either too much ink or an improper ink/water balance. This results in ink emulsification or scumming. During the platemaking process, dots can either grow or shrink depending on the orientation of your film/plate process.

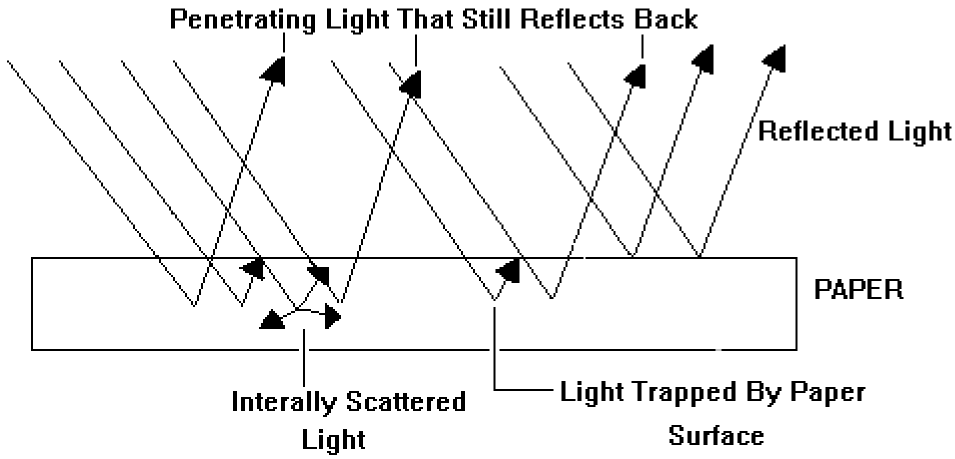
If you are using negative working plates, exposure during platemaking will cause a dot gain of roughly 3% - 4% in the midtones. Positive working plates loose about the same during exposure which results in an overall difference between the two orientations of about 6% - 8%. Be sure you recognize this fact when comparing dot gain values with other printers.

Optical Dot Gain

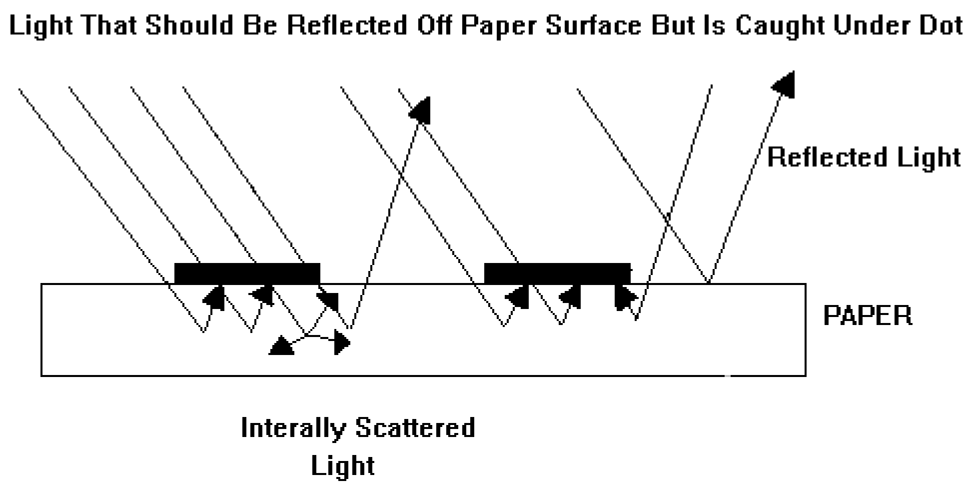
Optical dot gain refers to the appearance of a given halftone to the human eye, or densitometer, **when viewed at normal viewing conditions**. *To clarify, optical dot gain is the illusion of a given dot area; appearing larger than it really is physically*. For example an experienced pressman may view a halftone under a loupe and determine that it is a 50% dot area, where the edges of each dot just touch. But when that same halftone is viewed by the naked eye from typical reading distance it appears as a 60% or 70% dot area. This apparent added dot area is optical dot gain.

This illusion is generally caused by the paper and ink, or dot, interaction. Paper being a porous substrate, does not actually reflect back 100% of the light that hits it. And when ink is added to the paper in the form of dots this absorbance of light by the paper is exaggerated further.

Light’s Reaction with Paper



Light's Interaction with Paper and Ink



As you can see from the illustrations, light reacts with paper in many different ways. Light can be absorbed completely, scattered internally, or reflected either from the surface or just under the surface. When halftone dots are added to the surface of the paper, the light that penetrates and normally reflects is affected. The light penetrates the surface but gets trapped by the ink. This allows the ink to block more light, hence adding to a dot area or dot gain reading.

What do we see and what does a densitometer see? Humans and densitometers view light and its interaction with ink/paper the same way. If a dot gains under a densitometer, it will also appear to gain to the human eye. So do we see mechanical or optical dot gain. The answer is both. The sum is called ***visual or apparent dot gain***. When a dot gain measurement is taken by a densitometer using the Murray-Davies equation, it is measuring visual dot gain. But if the densitometer calculates dot gain using the Yule-Nielson equation the answer is mechanical. The Yule-Nielson equation utilizes an n-factor to "factor" out the optical dot gain. The equation is the same as the Murray-Davies with this added factor :

$$\frac{1 - 10^{-(Dt/n)}}{1 - 10^{-(Ds/n)}} \times 100$$

Where : n is an <u>empirically</u> calculated factor

Here the n-factor is used to cut back the total Ds and Dt. As the n-factor becomes larger, the dot area becomes smaller. So a dot area calculated with an n-factor of 1.65 will be less than that calculated using an n of 1.00. The Murray-Davies equation is equivalent to the Yule-Nielson with n set to 1.00.

Determining n-Factor

The n-factor is experimentally determined by adjusting the n-factor until the densitometer reads the ‘desired value’ at a known dot percentage. Typically a 50% tint is used because it is easy to spot. Print a number of tint values close to 50, say 40 and 45. Use a magnifying glass or loupe to find the tint patch that ‘looks like’ a 50% tint. Next adjust the n-factor until that patch reads 50%.

<u>A new n-factor should be determined for each type of substrate used</u>! It may not be necessary to calculate a separate n-factor for each stock used, but it is a good idea to have one for each grade of paper: coated, uncoated, newsprint, RC, etc. An n-factor may be used for film readings as well but typically it is not done.

One thing to keep in mind is that the n-factor is just a coefficient or correction factor. It helps to compare dot gain of uncoated paper to coated paper. It may not be necessary to use the Yule-Nielson equation if the same stock is always used. Also communicate that an n-factor was used when comparing dot gain with other printers or service bureaus!

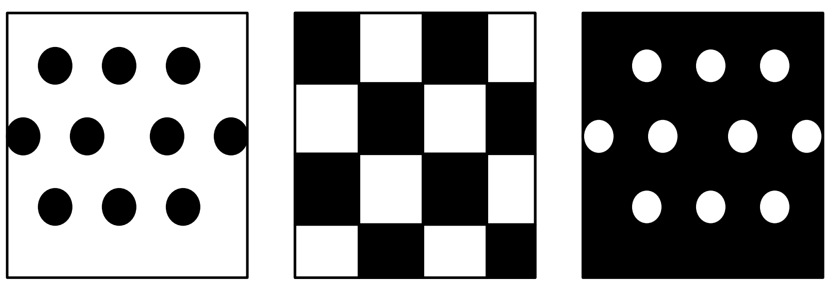
Characteristics of Dot Gain and Dot Area

Many things affect dot area and dot gain readings. Most are press related in terms of packing, ink tack or blanket type. It is beyond the scope of this abstract to identify all contributing factors to dot gain, but there are several general characteristics that are important to keep in mind when interpreting dot area and dot gain readings. These things should help point to the cause of excessive dot gain, or better yet, help point away from things that may seem to be problems.

First of all, dot gain is not bad. It is inherent to the printing process and will always be there in conventional pressrooms. Also, as stated before, dot gain has many sources all of which are unique to a specific printing environment. Therefore, because Printer A has presses printing with 16% dot gain and Printer B prints with 22% does not mean A is better than B. However, it does mean they are different, and that is the most important point to recognize when dealing with these readings. Approximate average of dot gain throughout the pressroom is also important to the prepress department because they can correct for this inherent printing characteristic.

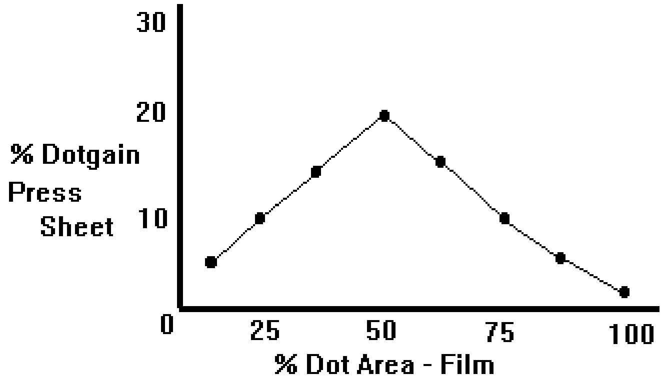
Secondly, dot gain affects the midtones (50%) the most. This is due to the fact that the 50% dot is the largest dot formed in the halftoning process. Studying the dot structures below will illustrate this fact. The affective perimeters of the 25% dot and 75 % dot are identical.

25 % tint   50 % tint   75 % tint



The 50% dot has much more "shoreline" to be affected by dot gain than either the 25% or the 75% tints. In fact when dot gain is talked about in general, it always refers to dot gain occurring in the 50% tint patch because it is greatest there.

Examining a dot gain curve further reinforces this statement.



We can see that dot gain peaks at the midtones and drops off symmetrically on either side. It is typical to have higher dot gain in the 55% tint than the 80% tint. Screen ruling also affects dot gain readings. The higher the screen ruling the higher the dot gain. This too is due to the fact that there is more perimeter (more dots) with higher screen frequencies.

Make Sure You Know What You Are Measuring

Typically dot area and dot gain are measured in separate steps during the printing process. Final films, proofs and press sheets should all be measured to ensure proper dot reproduction throughout the process. Understanding the difference between these separate steps is critical if you are to understand the data you collect.

Two different types of densitometers are used to measure dot area and dot gain. A ***transmission densitometer*** is used to read dot areas ***through*** films. A ***reflection densitometer*** is used to read dot area ***reflected off*** substrates, such as proofing papers and printing paper. Although these instruments are unique in the way they read dot area, the measurements obtained are calculated in the same way. Hence you are comparing apples to apples when taking about dot area/dot gain from either instrument.

It is very important to understand though that when comparing press sheets to proofs we are looking at two very different reproductions.. A major point to remember is that none of the proofs use the same ink as is used on presses. If that were not enough, the way dots are applied to the substrate is totally different than the pressure/adhesion technique used by the press. In fact, most proofing processes do not use pressure at all when applying dots to paper. Therefore, there is no mechanical dot gain in most proofs. These proofing systems must use optical dot gain to simulate the mechanical and optical dot gain found on press. One way optical dot gain is introduced to the proof is by using a light diffusing layer on top of the proofing "ink" or below it. This scatters the light even more, creating more optical dot gain. An interesting project might be to compare dot gain curves of a press sheet to a proofKeep these things in mind when trying to match the proof with a press sheet. Realize that you are trying to match a simulated press sheet with simulated inks and simulated dot gain.

One final point. As with all measurements of any type, the single greatest source of bad readings comes from bad technique and operator error. Be consistent when taking readings. Is an n-factor used or not? Have you selected the correct filter? Was the sheet read on a white surface or a black surface. (Incidentally ANSI standards specify the use of a black backing material of 1.50 or higher density when taking densitometer readings). Careful consideration must be taken when training and standardizing the way densitometers are to be used in your printing facility. Remember quality decisions will be made with these data; bad data yields bad quality decisions.