UNDERSTANDING & CONTROLLING HALFTONE DOT GAIN

by
Mark A. Coudray

With the possible exception of moiré, dot gain is the most troublesome challenge that we face when printing halftones. Dot gain is not unique to screen printing, in fact, all printing processes must deal with it. With screen printing, the amount of gain we experience can be extreme.

The many causes of dot gain all end with the same result, reduced contrast and a shortened tone range. To the observer this means the the reproduced image will appear flatter and darker. Hues or colors will often be darker or badly distorted. Some subjects are more prone to dot gain than others. Knowing this will help in evaluating your art when it is presented to you.

When dealing with four color process, dot gain can be fatal. Indeed, one of the most common comments that I hear is "my images often look dark and muddy." This is the visual definition of dot gain; image darkening and loss of contrast. Most often the color separator gets the blame. More often than not, he is to blame from the perspective that he underestimated the amount of gain, and at what point in the tone curve the gain will occur. As a printer you must be aware of what dot gain is and how to determine how much gain you are experiencing. This information is very important to the separator in preparing film that will work for you.

We measure dot gain with a reflection densitometer on flat substrates. Most modern densitometers will allow you to measure the gain with or without the influence of the substrate. A good color reflection densitometer that measures density, dot area, dot gain, print contrast, hue error and greyness, and trapping will cost between $1700 and $2400. This is a significant expense, but if you are serious about process color it is an essential investment. This device is important because it not only measures the amount of dot gain, but allows you to check the consistency of the printed area over the course of the run.

If you cannot afford to obtain one of these instruments the best alternative is to look at the printed piece and compare it visually to the known artwork if it is available. Do not consider the color overlay or laminated proof as the gospel. Because of the corrections necessary for screen printing, the color proof provided by the separator is only a guide. It

©1994 Coudray Graphic Technologies :: 805.541.1521

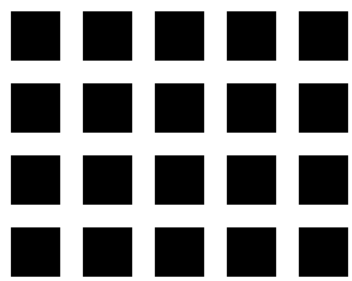
is much better to reference the original artwork if you can. If you are very new to this, print a sample of the entire job and send it with the color proof back to the separator for guidance.

Dot gain has many sources. It can be related to the stencil, the ink characteristics, the printing set-up, or absorption of the ink by the substrate. Another way of looking at dot gain is that the halftone dot is growing or spreading during the printing process. In order to get the upper hand we must eliminate the spread or compensate for the spread in other ways.

Let's start with the halftone dots on the film. The continuous tone original is converted to a dot that represents the visual density value of the tone in that area. In other words. We start with white and end with black on our tone scale. The various shades or tones along the scale are achieved by producing dots of varying size. No dot represents white, a solid area represents black. The various tones are achieve by having the eye mix the white space with the the printed dot. The finer the line count of the halftone, the more visual mixing occurs. This has the effect of approximating the continuous tone of the original. As the dot gets finer, the contrast level also drops, and this causes the reproduced image to look "flat."

Each line count will have a different amount of compensation applied by the separator to take this into effect. When the separator underestimates the amount of dot gain, the printer is in big trouble. We use to say that if the color proof looked good and saturated there was no way that we could print the image and have it end up looking good. This is definitely true for the finer line counts (above 85 line) in screen printing. The proof will not represent the final print, it will be inaccurate.

There are two types of dot gain that we are concerned with. The first type occurs naturally and is referred to as "optical dot gain." This type of gain can actually be considered part of the basis for the halftone process and is the mixing of black and white to fool the eye into thinking that it is seeing grey. Most of us have seen the optical illusion of the black squares and intersecting white lines. As we look at the illusion, our eye soon fatigues and we see phantom grey images at the intersections of the black and white. The grey images appear to dance and move as we consciously try to focus on them (see figure.) This is optical gain at its best.



Another type of optical gain occurs when the printed image interacts with the substrate. This is most noticeable when the substrate is a translucent white. What happens is that the printed image tends to create a grey halo or fringe around the perimeter of the dot, causing it to appear darker. The stronger the light under which this is viewed, the greater the gain will appear. With backlit displays this can be very troublesome. Another name for this effect is halation or light scatter. We experience the same situation when we image our screens and light travels down the translucent threads of our monofilament mesh.

A third type of optical dot gain relates to the substrate surface that the image is printed on. If the surface is not perfectly white (it never is), it will add density to

©1994 Coudray Graphic Technologies :: 805.541.1521

the image. This is a problem when the backing material of the color proof is whiter than the substrate that you are printing on. Even if you control the gain in the printed piece, the added density of the paper will have an effect on the image. Because of the logarithmic nature of density, the addition of the substrate is most noticeable in the highlight, quarter tone, and mid tone regions of the tone scale.In addition to overall added density, the substrate can be responsible for significant color shifts to the yellow or blue regions. Try printing one image on a number of different substrates to see the effect.

With all types of optical dot gain, the finer the dot, the greater the apparent gain. If you are selling process color images that are to be viewed as displays, take this into consideration. It is very common for an advertising agency to specify 85 or 100 line halftones for displays that will be viewed three or more feet away. Unfortunately, the art directors are not aware of optical dot gain and are requesting this requirement based on printing purchased for normal reading purposes (10"- 18".) A very good way to deal with this is to print two different line versions of the same image with the same amount of dot gain correction, and view them from the proposed application distance. I guarantee you that the finer image will look flat and washed out due to this optical gain phenomenon.

The second family of dot gain is physical. This is the actual growing or enlarging of the halftone dot. Before we get into the causes of physical dot gain we should examine what occurs as the dot grows.

Dot growth can occur in two ways with screen printing. The first is perimeter or border dot gain. This is not unique to screen printing, in fact it occurs with all printing processes. Border dot gain has serious effects on the size of the dot because it is relative to the diameter of the dot. This gain starts in the highlights and increases at a relatively uniform rate through the quarter tones. The midtones experience a steeper rate of growth which decreases somewhat through the three quarter tones. Dot gain continues at a decreasing rate in the reversal to shadow dots. The finer the line count, the more growth you can expect. As the line count get coarser, the rate of growth decreases.

If our printing process adds a constant amount of dot gain, the effect will be dramatic over the different line counts. Consider the fact that the following represents the number of dots in a given square inch of halftones at the following line counts.

Line Count	Dots Per Sq Inch
35	1225
45	2025
55	3025
65	4225
75	5625
85	7225
100	10,000

It is easy to determine that the number of dots per inch, each gaining at an equal rate will be extremely difficult to control as the line count gets finer. I would much rather manage the dot gain on 4225 dots per square inch at 65 lines than I would 10,000 dots per square inch at 100 lines. We have already discussed the optical effect of the finer line counts. When we couple it with the physical effects, the tone range can all but disappear.

The message here again, is print with as coarse a dot as you can in order to get the best possible tone range. There is a real tendency in our business to apply what I

©1994 Coudray Graphic Technologies :: 805.541.1521

call the "macho factor" to halftone printing. This is where the printer tends to go with the finest dot he can get so that he can say he prints 120 line halftones, etc. In most cases this is a mistake not only from the added difficulty that is entailed in printing the job, but in the visual look of the final printed piece. Too fine of a line count fails more often than it succeeds.

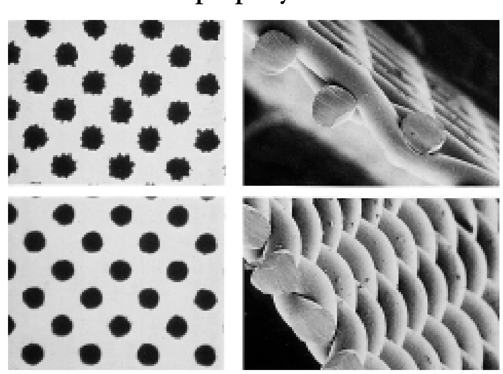
So far we have discussed the families of dot gain in a generalized manner. Now let us consider the sources in the printing process and how to minimize the impact. These sources are screen stencil making, press set-up, ink characteristics, printing, and drying.

In the screen making phase it is important to use the thinnest possible deposit of ink. The larger the thread diameter, the higher the column of ink that you will be depositing on the substrate. In textile printing this is one of the most significant causes of gain, too much ink on the substrate. UV printers are also well aware of the dangers of "topographic issues" relating to too much ink on the substrate. We want to control the volume of ink on the surface so as to minimize its growth and spread. It stands to reason that if we minimize the column height of ink deposit, there will be less physical volume to spread around the border.

I have always been a proponent of using meshes of the 33 to 40 micron range. Note that I do not specify the mesh counts, only the thread diameters. The mesh counts chosen depend on other issues which have been discussed in previous articles on Halftones and Moiré (reference prior series.) I do not feel that thread diameters finer than 33 microns will support the level of mesh tension that is necessary for proper ink transfer.

For the past five years or so discussion has centered on the comparison of plain vs twill weave fabrics. There is no doubt that plain weave meshes exhibit more latitude in maximizing accurate dot deposit. Our experience with high solids emulsions has shown that if the stencil is 6-8 microns proud of the mesh, the effective gasket seal will tend to minimize the irregular ink deposit that results from the twill mesh. This, combined with the improved ink transfer at the extremely high tensions (50 N/cm +) of some of the new generation twill fabrics, have minimized the differences between the plain weave and twill meshes. There needs to be more research done to quantify the effect of stencil, mesh tension, and ink characteristics,and their inter-relationships. I feel confident that within the next few years we will finally have a predictable formula that can be used in a practical manner.

The stencil is a critical part of the equation. It is necessary that the print side of the stencil provide a very accurate gasket that will seal the edge of the halftone opening as the squeegee passes over. If it does not, the resulting dot deposit will exhibit rapid border dot growth. With twill weave meshes at tensions below 25 N/cm, we also see the round dot being transformed into more of an eight pointed star. (reference the SAATI photomicrograph Peyskens page 110 fig 87a 87b) Indirect, capillary, and high solids dual cure photopolymer emulsions give excellent edge definition and sealing characteristics. The finer the dot you are printing, the more critical it becomes to seal properly.



©1994 Coudray Graphic Technologies :: 805.541.1521

The press set-up is closely related to the ink flow characteristics. Most printers determine their set-up based on how the ink flows and is deposited. The two most common situations are too much off contact and too much squeegee pressure. If you are going to be successful in controlling dot gain, you must minimize both of these situations. In the first circumstance, off contact is the separation distance between the print side of the screen, and the substrate. The distance is determined primarily by the mesh tension and the ink viscosity. By printing with the highest possible tensions we can minimize the off contact distance. The lower the off contact distance, the less squeegee pressure is necessary to stretch the mesh down to the print surface.

The reason that we must control these two items is that if the off contact or squeegee pressure are too high, the ink will be pre-expressed through the mesh and stencil openings prior to deposit on the substrate. This has the effect of providing a large reservoir of ink volume which will spread as soon as it hits the substrate. If the ink is pre-expressed through the mesh, the stencil cannot do its job of providing a proper gasket on the substrate surface.

Off contact distances in the order of .030" are possible with high tension mesh for image areas up to 24" x 30". The off contact distance will increase slightly as the image area increases. It has been my experience that by carefully controlling the amount of vacuum and using high mesh tensions, it is rarely necessary to have off contact separation greater than .060" over areas up to 35" x 48".

Free mesh also comes into play, but it too is governed by the mesh tension. The higher the tension, the less free mesh is required. The rate of dot gain across the screen is not uniform. It increases dramatically toward the outer edges of the image. If the squeegee pressure is not uniform, the rate of dot gain will be proportional to the increase in pressure. Simply stated, the more squeegee pressure, the more dot gain.

While we are on the subject of press set-up, we should also investigate the roll of the flood bar. In the U.S. it is common to use blades that have the effect of “bulldozing” the ink through the mesh opening. This is characterized by the ink bead having a counter clockwise roll during the flood stroke. This has the effect of pre-expressing the ink through the mesh opening. If the flood pressure is too great the effect is compounded.

To minimize the pre-expression at this stage, you must use the type of blade popular in Europe. It is what I call the “snowplow” blade. It causes the ink bead to roll clockwise away from the mesh opening during the flood stroke. A very minimal ink reservoir is provided to the mesh opening, resulting in a dramatic reduction of the pre-expression of ink. By carefully reducing the pressure on the floodbar and using this type of blade in conjunction with high tension mesh we can almost eliminate the cause of dot gain at this phase of the printing cycle.

The ink plays a critical role in controlling gain. An ink that is thixotropic is essential. This condition is where the ink is at high viscosity at rest, and dramatically reduces its viscosity when a shear force is applied to it. The greater the difference between the resting viscosity and the printing viscosity, the better the chances of controlling gain.

Once the ink has transfered from the screen to the substrate, the reversal to resting viscosity helps to control the flow out or border gain of the dot. If too much reducer is added to the ink, the thixotropic characteristics of the ink will be destroyed,

©1994 Coudray Graphic Technologies :: 805.541.1521

and the printer will lose the advantage of the unique property.

While we are on the subject of reducers, it is a common tendency to add a great deal of reducer to the ink to keep solvent based systems open in the mesh. Not only does this effect the thixotropic characteristics, but it makes it very difficult to maintain consistent color densities. As the solvents evaporate, the color will change as the ratio of solvent to pigment changes.

Another consideration regarding the ink and solvent combination is the absorption of the substrate. The more porous the substrate, the greater the penetration into the material. On coated papers and nonporous materials the following ink densities are good starting point. If you are new to halftone printing, stick to the lower end of the range.

Yellow	.80	–	1.00
Magenta	1.20	–	1.40
Cyan	1.20	–	1.40
Black	1.40	–	1.60

These ink densities are measured as a solid patch with a densitometer (wide band) and have been chosen to print the correct neutral grey when the Yellow, Magenta, and Cyan are combined. It is important to maintain the same ratio of color strength for each of the combined colors. If you choose the low end of the range the ratio would be: Y.80 : M1.20 : C1.20.

For uncoated substrates decrease these densities by .10 – .20. Because of the absorption and optical dot gain, the lower ink densities will yield the same visual color as the higher densities on coated stocks.

To combat both the thixotropy issue and the evaporation and color shift issue, try reducing the ink with what I call a reducer paste. This is a mixture of the slowest retarder you can use with the ink system, and aerosil or cabosil (fumed silica). This paste will effectively keep the ink from drying in the mesh while simultaneously maintaining the slow flow characteristics necessary for halftone printing. Remember, that the higher the mesh tension, the higher the viscosity that you can print with.

Another consideration with the ink is the effect of static on the dot structure. I have seen high impact styrene and vinyl radically effected by static. Depending on the dot count, the static charge will not effect the highlight, destroy the midtone, and leave the shadow relatively intact. What appears to happen is that the ink is of one charge, and the substrate the opposite. The highlight dots are far enough apart that the charges do not interact. In the shadow areas, the dot structure in interconnected and the charges flow throughout the network. In the midtones, the dots are just far enough apart that the charge will cause the ink to "arc." This is similar to cobwebbing or ink flying, but it has the effect of causing the midtone dot to literally appear to explode. From a distance this causes the midtones to look like you put your thumb in the wet ink. All the detail and tone are destroyed. It is even more troublesome in that it is not consistent. It can be highly localized and it can shift at random depending on the concentration of static on the surface of the substrate. The thinner the ink, the greater the tendency. The finer the line count of the halftone, the more prevalent throughout the tone range. Keep the ink as high in viscosity as possible to resist this situation.

Once the ink is down on the substrate, drying or curing should take place as quickly as possible. You do not want the ink to sit on the surface of the substrate as the more time it has, the greater the

©1994 Coudray Graphic Technologies :: 805.541.1521

chance that it will flow out or be absorbed into the surface. If you must air dry your stock, it is recommended that you keep your ink as high in viscosity as possible. If this does not solve the situation, try coating out the surface with either clear or a white underbase to stabilize and seal the sheet. I have had great success in doing this with solvent based inks on art papers. Not only does it reduce the dot gain, it helps control sheet growth and shrinkage due to temperature and humidity changes in the print shop.

Summarizing a basic strategy in controlling dot gain follow these basic guidelines.

1. Use as coarse a dot count as possible.

2. Use high solids direct emulsions or capillary films to get a good gasket seal.

3. Keep your mesh tension as high as possible, squeegee pressure and off contact low.

4. Floodbar should be snowplow type with low pressure.

5. Use the thinnest thread as possible in your mesh.

6. Keep ink viscosity high and use thixotropic base.

7. Above all make sure your separator knows how to recognize and compensate dot gain in the print.

It is not possible to eliminate dot gain, we can only compensate and minimize the negative aspects of it. As with all halftone printing, the more careful you are, the better will be your results. Keep good accurate records of each print run and study them carefully to recognize where you can improve the printing.

©1994 Coudray Graphic Technologies :: 805.541.1521