Technical Information

Moiré, Rosettes, and Color Shifts

[1]For background information on moiré, please refer to the Linotype-Hell technical information piece on Moiré, and the Linotype-Hell technical sample called What Factors Play a Role in Moiré?

Moiré in color printing is a complex phenomena. However, upon close investigation of the rosette patterns in four color printing it becomes clear that color shifts caused by the overlap of neighboring halftone dots are at the root of moiré. To understand why this is so, let's take a look at the history of process color printing. The past offers some interesting insights into the rules that govern how we deal with process color today.[1]

Halftoning

The invention of photography in the early 19th century provided the impetus for the development of halftoning. Printers needed a simple way to mass produce photographic images. Many inventors throughout the world were working in parallel on the concept of halftoning, including (in the United States) Frederic Ives, Stephen Horgan, and Max Levy. One of the earliest examples of a halftone was printed in 1880 in The New York Daily Graphic. By 1900, halftones were commonplace in weekly newspapers.

Early color printing

Color printing before 1890 was spot color printing. Each color in a print would be represented by a separate spot color. If you wanted to use ten colors in an image, then you would use ten inks. While you might achieve some color mixing by overprinting colors or through the use of fine hatching, the result was illustrative rather than photographic. Halftoning opened up the possibility of reproducing photographs, at first in black & white, but later in color.

Early halftones

The earliest halftone screens were called line screens. Halftones were photographed through glass that had parallel lines etched or drawn on them. The resulting halftone dots formed parallel lines of varying thickness, depending on the amount of exposure. (See Figure 1.) Some of the earliest color work was done with line screens, including one of the first three color printed halftones ever produced (1893, by William Kurtz in New York).
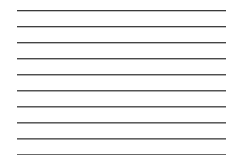

Figure 1 - Line halftone screen. The pattern in a line screen repeats every 180°. If a 0° line screen is rotated 180°, it appears the same as it was at 0°.

[2]At the time, the process color primaries were referred to as yellow, blue and red. It wasn't until much later that the terms *cyan* and *magenta* came into common use. Even today, cyan and magenta are often referred to as process blue and process red. The term *process* comes from the many color photographic processes that were introduced in the early 20th century (for example, the Dufay Process, the Pinatype Process and the Warner-Powrie Process). Later, the term *process* was used to describe a wide range of printed color.

Very quickly it was discovered that tremendous moiré patterns could occur when two halftones were printed on top of each other, particularly when there was no difference in the screen angles of the two halftones. Early color printers found that they got the best results by using line screens that were offset by 45°. They printed in three colors and set the screen angles as follows: yellow at 0° (i.e. horizontal), blue at 45° to the right of vertical, and red at 45° to the left of vertical.[2] (See Figure 2.)
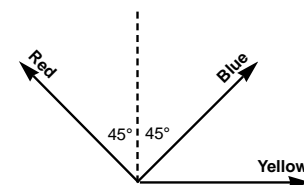
No screens were set vertically because of the observation that the eye tends to easily pick out vertical lines (as opposed to lines at an angle). Note that the lightest color is horizontal, while more noticeable colors are set at 45°.

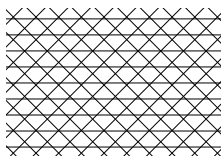*Figure 2 - Early color separation angles for a line screen.*

Figure 3- A black and white representation of the pattern that three line screens would create if set at the angles shown in Figure 2.

In the late 19th century, most printers would buy two screens if they were printing color, one straight (with the angle set at 0°) and one diagonal, (with the angle set at 45°). The 45° screen could be flipped so that it could be used for both blue and red. (See Figure 3.) Common screen rulings ranged from 30 to 200 lines per inch, and of course you had to buy a different glass screen for every screen ruling you wished to reproduce. Press registration was generally very poor and was a critical issue for anyone printing color.

Around the turn of the century, it became apparent that if you made the halftone screen on a round piece of glass, it could be easily rotated to provide any screen angle. More experimentation with screen angles followed.

Color shifts

Though it is true that screen angles are shifted to avoid moiré, there is a more important underlying reason: color shifts. If two neighboring colors have the same screen angle, then variations in press registration mean that for some press sheets, the colors may overprint exactly, and in some they may print side by side. When the screen angles are all the same, press misregistration affects every halftone dot in the same way. (See Figure 4.) However, if you give each separation a different screen angle, then shifts in press registration do not have as dramatic an effect. (See Figure 5.) And while this is obvious in black & white, with color another issue is important. Inks are supposed to be perfect filters of light, but in truth they are not. Therefore, because of ink imperfections, colors overprinted, and colors printed side by side will produce different colors. The result is a color shift.
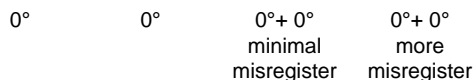
| 0° | 0° | 0°+ 0° minimal misregister | 0°+ 0° more misregister |

Figure 4 - Overlap of neighboring halftone dots when the screen angles are the same.

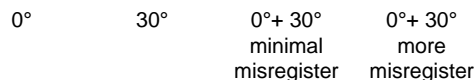| 0° | 30° | 0°+ 30° minimal misregister | 0°+ 30° more misregister |

Figure 5 - Overlap of neighboring halftone dots when the screen angles are separated by 30°.

Lines and crosslines

When choosing screen angles for three color separations, early color printers needed to know the type of halftone screen in use. With a line screen, the pattern created by the lines repeats every 180°. This means that if you rotate a line screen by 180°, it appears the same as it would at 0°. Therefore, if you want to put yellow, blue and red color halftone separations at three different angles, it make sense to separate them by 60° (i.e., 180/3). That means putting one at 0°, one at 60° and one at 120°. (See Figure 6.)
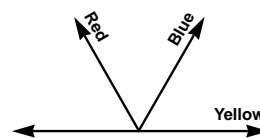

Figure 6 - Line screen color separations separated by 60°.

Another type of halftone screen in use at the time was called a crossline screen. Crossline screens are made up of two sets of parallel lines set at 90° to one another. (See Figure 7.) Because the crossing lines are perpendicular to each other, the halftone dots that are created form a pattern that repeats every 90°. This means that if you rotate a crossline screen by 90°, it appears the same as it would at 0°. For color printing with a crossline screen, therefore, it makes sense to rotate each screen by only 30° (i.e., 90/3). The screens should be placed at 0°, 30° and 60°. (See Figure 8.)
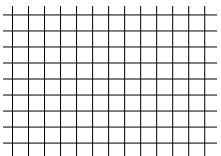

Figure 7 - Crossline halftone screen. The pattern in a crossline screen repeats every 90°. If a 0° crossline screen is rotated 90°, it appears the same as it was at 0°.

It had been discovered that line screens didn't reproduce detail so well in the highlights and shadows, and so by 1895 most everyone was using crossline screens, particularly for color. Today's round or round/square halftone dot is similar to a crossline screen in that its pattern repeats every 90°. An elliptical

dot is similar to a line screen in that it repeats every 180°. But an efficient elliptical dot doesn't have the disadvantage that a line screen does (i.e. poor reproduction in shadow and highlight) because most elliptical dots are only elliptical in the midtone area, in the highlights and shadows they are actually round. So instead of narrower and narrower lines, which may disappear in high-lights or fill in in shadows, there are printable circular halftone dots.
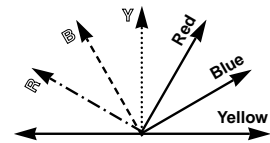
Figure 8 - Crossline screen color separations separated by 30°.

The orientation of line and crossline screens explains why a 15° screen is the same as a 105° screen for symmetrical halftone dot shapes (like round). In the case of an elliptical screen, 15° and 105° are not identical. A 105° screen would have the ellipses running perpendicular to a 15° screen. A 195° screen would be identical to a 15° screen because it is separated by 180°.

Four color printing

In 1891 a German lithographer named Ulrich decided that he could print better-looking color by using a fourth color, either black or gray. Although four-color printing didn't catch on immediately, the seed was sown. And this presented a dilemma for everyone who was doing three-color printing. At what angle do you put the fourth screen?

Initially it was thought that the colors should be separated by 22.5° (i.e. 90°/4), but this didn't produce good results. Another German, Dr. E. Albert determined that a 30° separation of the darker colors (red, blue, black) was best, and that yellow should be inserted between red and blue, only 15° from each. (See Figure 9.)
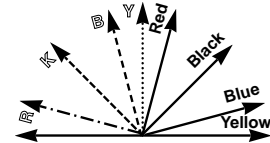
Figure 9 - Four-color separation angles developed by Dr. Albert.

[3]For more information, please refer to the Linotype-Hell technical information piece called Rational and Irrational.

This solution, which was devised before the turn of the century is very similar to angle and ruling combinations that we see today. Of course, digital halftoning techniques have changed the rules in one important way. Some digital halftoning methods introduce slight variations into the screen angle and the screen ruling of a halftone. This means that following the century-old screen angle and ruling recommendations may not always be the best option for modern screening methods.[3]

Moiré

What exactly is a moiré? A pattern that is created when two or more repeating patterns are overlaid. Overlaying two halftone patterns at slightly different angles creates a strong moiré. If you look closely at Figure 10 you will see that the pattern results from the relation-

Figure 10 - Moiré between two screens at slightly different angles.

ship between overlaid halftone dots. Where the halftone dots coincide exactly, it appears that there is only one halftone dot. Where they are out of phase, the result is a double halftone dot. Of course the double halftone dot is larger, and as a result the areas with double dots are darker.
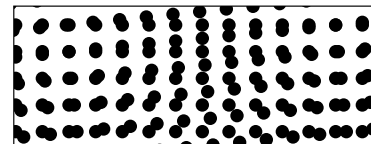
The situation is very similar with four color rosettes. A moiré in four color work is really only the difference between a dot-centered rosette and an open-centered rosette (see Figure 11). If you will look at Figure 12 (next page) you will see how the variation from a dot-centered rosette to an open-centered rosette defines moiré. Therefore a moiré and a color shift are linked together by definition.
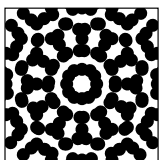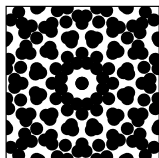
If a moiré pattern in four color printing can be described as the shift from open-centered to dot-centered rosette, and a dot-centered rosette is darker, then what you are actually seeing is a change from light to dark. What happens in a moiré? A repeating pattern is visible. Why is it visible? Because certain areas are darker than others.

Figure 11 - Dot-centered rosette (top) and open-centered rosette (bottom).

Moiré period

One important factor in moiré is called the moiré period. Moiré period can be defined as the distance from an open-centered rosette to a dot-centered rosette and back to an open-centered rosette. When the proper screen angle and ruling recommendations are used with RT Screening*, a rational screening method, this distance is very short, a fraction of an inch. (See Figure 13.) With HQS Screening*, a supercell rational tangent screening method, the moiré period is much longer, usually a foot or two (enough so that in an average page, you don't see both an open-centered and dot-centered rosette). With I.S. Technology*, an irrational tangent screening method, the moiré period is infinite.
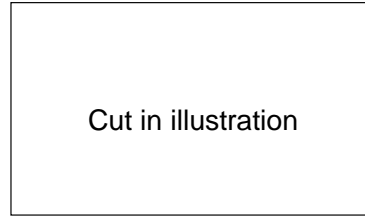

Figure 12 - Dot-centered and open-centered rosettes in a moiré pattern.

Figure 13 - Black & white depiction of an RT Screening rosette (using recommended values). Unconventional-looking dot-centered and open-centered rosettes appear nearly side by side.

It is easy to see the difference between the rosettes of rational tangent halftones and supercell rational tangent halftones. It is not so easy to see a difference between supercell rational tangent halftones and irrational halftones. The reason for this is that the rosettes are very similar, the difference is in the moiré period. Comparing single pages of these two techniques is not enough. The only way to compare is these methods is to look at many sheets in a press run. Irrational tangent halftones, because of their infinite moiré period, will be more consistent over a press run.

Screen sets

In addition to infinite moiré length, I.S. Technology features three screen sets for different angle combinations:

• I.S. Technology 10 uses angles of 0°, 45°, 105°, and 165°. Note that the 45°, 105°, and 165° angles are separated by 60°. This is appropriate for use with all halfone dot shapes, including elliptical.

• I.S. Technology 20 uses angles of 45°, 60°, 105°, and 165°. This set shifts the yellow separation from 0° to 60°.

• I.S. Technology 30 uses angles of 7.5°, 52.5°, 112.5°, and 172.5°. This is the I.S. Technology 10 set shifted by 7.5°. This shift is necessary in flexography, gravure and screen printing[4] to avoid screens that fall at 0° or 45°.

[4]Screens at 0° and 45° may conflict with the mesh of the silk in silkscreen printing. Similar conflicts can occur in flexography and gravure.

Comments

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