UNDERSTANDING HALFTONE MOIRÉ

by
Mark A. Coudray
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Of all challenges encountered in screen printing halftones, moiré is probably the most frustrating and difficult to deal with. For one thing it seems to be totally unpredictable in nature, appearing and disappearing at random. Practice and observation over the last 15 years have resulted in identifying a number of causes for this effect. Before we get into the causes and types of moiré, you should have at your avail two or three different inspection devices. The minimum would be a 10 X color corrected loupe and a 25X - 30X hand-held microscope. I would also recommend a 100X microscope as well. These are available in the $50-$250 price range from a number of suppliers. The finer the dot that you will be printing, the higher the magnification that you will need. Without these, you will not be able to observe what is happening to the halftone dot.

To begin, moiré is named for a French physicist who studied the mathematical relationships of repeating patterns overlaid on each other. Moiré patterns are present all around us. Picket and chain link fences often create patterns. Moirés are also found in stockings (silk or nylon) and in many woven designer fabrics. While watching television it is often possible to pick out moiré patterns in window coverings (miniblinds) or when viewing through window screens. In the technical world of optics, moiré patterns are used to measure extremely precise movements, often in millionths of an inch. For us, moirés are most often destructive to our images. They can appear as bands, lines, checkerboards, diamonds, or generalized tone distortions. They can be pervasive through the entire image or localized in specific areas. We have a real need to understand them and learn how to correct or minimize their presence.

Let me say at this point that it is not possible to totally control moiré. No matter how careful we are, there are simply too many variables that can have an effect on the formation of moiré. The challenge comes in the fact that some of the primary causes of moiré are in areas that we have no control over. After completing this article, you will have a much better appreciation of the complexity of the subject. You may even wonder how it was possible to get anything printed! As with almost all aspects of screen printing, the finer the detail or line count of the halftone, the more difficult the moiré is to control. With very fine halftones (above 100 lines) it is very important to follow the recommendations closely.

Moiré patterns can occur on a number of different levels. They can occur between:

1. The artwork to film halftone (artwork to film).
2. Type of laser generated film dot (film to film and film to screen.
3. The angles of the halftone films (film to film).
4. The halftone dots and the screen mesh (film to screen).
5. Angle of the halftone films and the angle of the mesh (film to screen).
6. The image and the substrate surface (screen to substrate).
7. The ink viscosity and the substrate (ink to substrate).
8. The printed layers of ink (ink to ink).

At each generational level there is the potential for generation of moiré patterns. In order to minimize the possibility of formation, we must be very systematic in our approach. Elimination of variables and standardization of methods are crucial to our success. If you do not follow this regimen, moiré will appear and disappear in a seemingly random manner. This can be extremely frustrating, as well as disastrous to production efficiency.

One of the easiest places to start is the artwork itself. As mentioned earlier, moiré can occur naturally in our environment. We can also have subject matter that will result in the formation of moiré patterns as soon as artwork is photographed. Examples of this would be any regular pattern in the original subject matter– fabric patterns, wicker chairs, fences, screens, window blinds, floor patterns, and any similar materials that have a regular repeatable surface texture.

Another major cause of moiré in original art results when a client provides the printer with a previously printed poster or related piece. This artwork already has the dot pattern in it from the first-generation printing. To minimize this, it is recommended to order a 4" x 5" reproduction transparency from which to separate. In the process of making this transparency, the dot pattern is usually reduced to the point where it blends smoothly together. Now it can be separated without the formation of dot to dot moiré.

When film is generated with a laser scanner or imagesetter, be particularly careful of the edge definition of the halftone. In first generation high end laser scanners (DS, Hell, Crosfield) the output resolution of the laser was not particular high. The ability to create an electronically generated dot (EDG) was primitive. In doing so, edges of the dots in the highlight areas were rough and irregular as the laser generated a series of on and off approximations of a circle. The finer the dot, the rougher the edge condition. Often the dots generated would be stars, or other irregular shapes. This was a real problem for printers that buy film in large format where the first generation halftone negative is produced at a very fine line count (150-300) and then projected to the final line count. All of the irregularities are projected as well. The newest scanners (in the last three or four years) have remedied this situation. Before buying film from a separator, examine a sample of the work under magnification to determine if the edges are sharp and clear.

With the introduction of PostScript® generated separations and laser imagesetters, we have a very real problem with the film. In addition to the selectability of the output resolution of the imagesetter, the EDG algorithms defined in PostScript® are not accurate enough at finer line counts. Separations generated with many of the new color programs available often do not deliver as promised. If you accept disks or film that is generated in this manner, always specify that the minimum output resolution be 1270 dpi on the imagesetter for coarse halftones (below 85 lines per inch) and 2540 or higher for fine halftones. I must emphasize that accepting film produced from the desktop environment is more trouble than it is worth at this point in time. The situation is improving, but it will be some time before it will be predictable and satisfactory. Do not tackle this area unless you are willing to do a lot of experimenting and trial.

A second major cause of moiré is the angle of the halftones to each other. In order to minimize the formation of dot to dot moiré, the three darkest process colors (magenta, cyan, black) are angled 30° apart from each other. Because the yellow is noncontrasting, it is sandwiched between at 15°. The difficulty for us poor screen printers is that the standard lithographic angles are:

Yellow	0°, 90°
Magenta	15°
Cyan	75°
Black	45°

The difficulty comes in the fact that 0°, 90°, and 45° are primary moiré generation angles. The reason for this effect is that the threads of the screen mesh will directly block full rows of dots as orientation of the dots is the same as orientation of the mesh. At 45°, knuckles of the fabric block the dots on a uniform basis. This means that halftones generated at these angles will almost always result in the formation of moiré. When buying separations from color separators who provide lithographic angles, you are flirting with trouble.

As with the mesh dot ratio, the finer the dot, the more important this becomes. The higher the mesh dot ratio, the less important this becomes. For any ratio lower than 4.0 : 1 we change the primary angles at which the separations are produced. The acceptable range of angle offset is ±4°-8° from the conflict angles. This is accomplished by either rotating the artwork off the horizontal baseline at the time it is separated, or by altering the angles that the scanner uses to generate the dots. The first method is the simplest, but results in more film being used, and a smaller maximum output size on the scanner. The second method requires homework on the part of the scanner operator. In fact, some scanners cannot generate film within this window, requiring you to use the first method.

A third option exists to compensate for this difficulty. It is to bias the mesh on the screen at the offset angles. I do not recommend this for a number of reasons. First, it is very difficult to accurately bias the mesh at exactly 4° on the frame. Secondly, when you bias the mesh using a stretch and glue system, the force of tensioned mesh is offset from the squeegee shear force. I am not sure what the overall effect on the stability of the mesh tension would be in such a situation, but my intuition tells me that we have enough trouble stabilizing tension when the threads are aligned in the direction of the force. If you are using a retensionable frame system, this is even more important as alignment of the tension on the mesh is now at a bias to the thread. Combine this with squeegee force and we have even more difficulty and distortion.

The type of moiré caused by an angular interference is generally uniform banding. With high mesh dot relationships, moiré will appear in the highlight area first. As the mesh dot ratio decreases, the moiré will progress throughout the tone range.

With ratios above 5.0:1 angular moiré is generally not a problem.

The next generation of moiré results from the mesh to dot relationship. Simply stated, this is the ratio of threads to the halftone dot. The formula is:

Mesh Count / Halftone Line Count = Mesh/Dot Ratio

or

355 threads/inch ÷ 100 dots/inch = 3.55 threads/dot

Over the years there have been all sorts of numbers and ratios thrown out as a guide in this area. The most common one is that the minimum ratio should be no less than 3.5:1. While I agree with this, there is much more to consider here.

Remember that moiré is caused by overlaying repetitive patterns on each other. When a moiré appears, our eyes are seeing dots that are not printing uniformly. Some are round, some are flat on one side, some may even be missing. The higher the ratio, the less chance there is of the dot being distorted as it is printed. For instance, with a ratio of 3:1 the dot could easily print as a square instead of a circle. If there is enough distortion between the rows of dots, our eye perceives a moiré.

In order to minimize repetition, there are two things necessary. First, print with the highest possible ratio. Any ratio above 5.0 will yield excellent results. Secondly, in the lower mesh dot ratios below 5.0, avoid any ratio that ends in an even first decimal place. In other words, avoid .0, .2, .4, .6, .8. It is even better if you can maintain an odd relationship in the digits and hundredths places (i.e. 3.55). The ultimate relationship would be one of a nonrepeating odd decimal. Realize that with the odd relationship, we are spreading out the occurrence of any pattern to the point that the eye can no longer determine a change in the pattern. We want to make sure that when the threads interfere with the dot, and block the opening, that the interference is different on each row of dots. This will result in rows of 8 dots that are different, but not repetitive. Even if the rows are different, our eye will not see it as a moiré.

Another word of caution with mesh dot relationships. The stated mesh count may not be the actual mesh count. All meshes are woven to metric standards, e.g. threads per centimeter. In the English translation we multiply centimeters by 2.54 to convert to inches. The resulting thread count is then rounded to the nearest 5 threads in most cases. A perfect example is where a 150 thread/cm fabric is converted to 390 threads/inch. In reality the conversion results in an actual value of 381. Please see the attached chart indicating the actual values when converted for some of the more common halftone meshes.

While we are on the subject of meshes, we should consider the reality that the mesh counts are not accurate. The warp count is fixed at the time the mesh is beamed up at the fabric mill. It is generally very accurate and true to the metric value. The weft count can vary substantially. It is not uncommon for the weft to vary ±5% of the stated value. I have seen it vary even more than this with some fabrics. This is one of the causes of localized moiré in an image that is out of our control. Weft count is not consistent throughout the run and, as a result, our ratios are changing within the range of variation.

One last point to consider with mesh dot relationships. The ratio is calculated based on the 50% dot at the selected line ruling. As the size of the dot changes with the change in percentage, the mesh dot ratio changes. The smaller the dot, the lower the ratio. This is why it is so important to maintain that odd to the first decimal relationship. The 10% dot is 1/5 the diameter of the 50% dot. If we use a 65 line halftone the initial ratio is 5.5:1. At the 10% dot the ratio changes to 1.1:1. This indicates that the 10% dot is just barely printable. As a printer your main consideration should be that the initial ratio is only a guide and is relative only to the 50% dot of the line count that you are calculating.

Because of this variable ratio, moiré that results from this source is often very localized in specific dot percentage areas. If you were to print a grey scale, you would see moiré appear only in certain steps of the scale. Most importantly, the shape of the moiré patterns will change with the changing mathematical relationship. This is very useful in determining the cause of your moiré. They will be banded in the highlights, changing to checkerboard/ diamonds as the scale changes toward higher percentages. This is one of the reasons that it is so difficult to print large areas of a single tone (e.g. sky or large skin tones). The very even relationships (150 dots on just about any mesh) will result in changing moiré at every step of the tone scale.

Thread diameter to dot area diameter is another source of moiré. It is very similar to the thread count to dot count ratio, but exhibits a slightly different characteristic. This type of moiré occurs with very small highlight dots (1%-5%) and with very fine halftones (120 line and higher). Upon close examination of the printed work, you will notice that entire rows of dots are missing. The visual effect of this is one of definite straight line voids in the affected areas. They may appear in one direction, or in two directions, at 90° to each other. This type of moiré is particularly difficult to control when the artwork has colors that have a very small dot (generally 1%-5%) of a tertiary hue. Examples would be light beiges and light greys. Other examples would be fleshtones and any greyed primary colors. This type of moiré also shows up when you have a color fading to white, as in a watercolor wash. The point at which it breaks to the white is where you will see disruption of the pattern.

You should be aware that if you change mesh counts, you run the risk of losing significant detail in the highlight areas. This most often happens when you switch from 330 or 355 to 305. When you drop to 305, the thread diameter increases from 34 microns to 40 microns. This will effectively eliminate the lightest tones and can cause a significant tone jump in the highlight areas. This is particularly true in textile printing where dot gain is a major problem. The reverse is also true: if you switch from 305 to a finer mesh, more detail will appear in the highlight regions. The visual effect will be a decrease in contrast in these areas as the whites will not be as white. The more dot gain you have, the lower the contrast.

To avoid this situation, consult your mesh data sheets to determine at what mesh counts the thread diameter changes. Use this information to make your decisions.

The fourth major cause of moiré is mesh tension. As with most aspects of mesh tension, this can get quite involved. There are several different reasons that affect the ink deposit and shape of the dots that are printing. A few guidelines are in order.

Always print at the same tension for all of your screens. Printing at different tensions on unstable mesh will result in different degrees of cold flow elongation (see SP Magazine May '90, Printing with High Tension Mesh). This causes the image to elongate in different amounts, altering the dot to dot relationship of the process colors and causing intercolor moiré (moiré between colors).

Another major aspect of mesh tension is that thread count varies with increasing tension. As fabric elongates during the stretching process, the number of threads decreases. It is not uncommon for a 355 mesh to end up at 305-310 when tensioned to 30 N/cm. Obviously, our mesh to dot ratio goes out the window if we have different tensions. Ideally, the mesh dot ratio should be calculated after the fabric has been tensioned to be truly accurate. The only way to do this is to stretch the fabric and then count the threads through a loupe to determine the actual number of threads per inch. If you print with different tensions, the thread/dot ratio will be changing at each tension level. It is possible to eliminate a localized moiré by adjusting the tension of the fabric of all screens up or down (preferably up).

The mesh tension also has an impact on the ability of the ink to transfer to the substrate. This is most affected in the highlight regions. At lower tensions (below 25 N/cm) and with higher viscosity inks, the ink will tend to hang up in the mesh and not print the smallest dots. The immediate visual impact is an increase in contrast of the highlight areas. Increasing the tension by 5-10 N/cm will most often overcome this situation. To determine if this is happening, look at the stencil with a loupe and determine if the image is open. If it is, increase tension. This particular situation is very critical when printing very fine halftones. In the case of 150 line, it can make the difference between obtaining any detail below 10%-15% in the tone range.

While we are on the subject of mesh, let's consider the significance of plain weave (PW) vs. twill weave (TW) and the thickness of the thread. If you have been in this industry for any period of time, you may be aware of the issue of plain vs. twill weave that was raised by Tamas Freska several years ago. Until recently, all meshes above 305 were woven in twill (one under, two over). Plain weave is woven one under, one over. The resulting contact points on the surface of the substrate result in a regular pattern with the plain weave, and a "herringbone" pattern with the twill weave. The resulting printed dot is badly distorted with the twill weave. This distortion can result in significant moiré, particularly in the highlight region of the tone curve.

The thread diameter and overall mesh height also have a bearing on the ink deposit. The thicker the mesh height, the higher the ink deposit. This additive ink height can result in significant "cross moiré" of the second, third, and fourth colors down. In order to reduce this, print with the thinnest mesh height possible. In the coming months look for several new developments in the finer mesh counts that should greatly reduce these difficulties. Those printers using UV will be the biggest beneficiaries.

Squeegee pressure can also cause moiré. It is most prominent with flat stock printing and is very much a factor with UV. The squeegee acts in conjunction with the surface topography of the substrate and the tension of the mesh. If the surface is rough and uneven, the likelihood of moiré formation is high. The more regular the roughness, the greater the probability of an undesirable pattern being formed. We often see this situation on fluted boards and textured cover stocks. With a low squeegee pressure, the dot is deposited on the "peaks" of the surface texture, never making it to the "valleys." The result is a dot that is distorted as only part of it is printing. As with several of the previous examples, the finer the dot, the greater the impact in this area.

In addition to the surface topography issue, we must consider the possibility that the dots are being slurred under too high a squeegee pressure. This results when the screen is printed under low tension, or too high an off contact. The mesh elongates as the squeegee passes, resulting in a stretched or slurred dot. If you look at the dot under high magnification, you will notice that the forward edge is sharp and clear, and the trailing edge will be soft or fuzzy. You may even see some distortion in the dot itself.

A possible solution here is to use the composite blades that are available. The 60-90-60 multi-durometer blades offer increased edge resiliency without too much blade flex. This allows for better ink transfer control, and better conformance to the surface topography of the image. Failing a multi-durometer blade, consider using a .015" spring steel backing on your sqeeegee. This will have some of the same effect as a multi-durometer blade.

In dealing with sqeeegee pressure, the printer must also be aware that the blade must be mounted perfectly flat in the holder. There is only one way to achieve this, mount the blade and then grind it. I am aware of the arguments for using new squeegees, but in my opinion, it is not possible to accurately mount even an 18" inch blade accurately enough. Invest in a good squeegee grinder that will allow you to sharpen the blade to within .002" per foot. This will insure totally even pressure being applied to the surface.

One important aspect regarding the squeegee pressure: the blade can be perfectly flat and sharp, but if the bed of the press is irregular (warped, dented, bowed, etc.), pressure will vary. It will also vary if the screen is not parallel or if the off contact and peel are improperly set. I strongly recommend careful service of your equipment with a qualified technician who measures with a dial indicator, not a straight edge or ruler. The TSF Multi-gauge is indispensable in this situation and I know of no other readily available device that will allow you to accurately set up the machine. If the machine is not parallel or even, there is a high probability of localized moiré. You will see this in the same spot on the sheet with different images.

Surface topography of the substrate can cause serious moiré difficulties. Whenever the surface is irregular, the dot will not conform, resulting in distortions. Depending on the nature of the surface there are two options available. The first is to lower the dot count as much as possible. This will help in reducing dot gain that may result with the added squeegee pressure necessary to penetrate the "valleys."

The second alternative is to clear coat the surface in an attempt to even the surface. This is an expensive proposition, but well worth it if it helps to eliminate moiré. The clear or fill coat can be done through coarser mesh as necessary to smooth the surface. A press proof is in order whenever surface texture is in doubt.

While we are dealing with surface texture, we must also deal with "cross moiré." This is moiré that results from the dot to dot buildup when printing fine line halftones with UV. This is caused by high solids of the UV, and the very small amount of ink film shrinkage that occurs during curing. It is most common in halftones above 85 lines and generally occurs in the quarter tone to three quarter tone region of the image. It normally occurs between the second and third colors, or the third and fourth colors.

There are three solutions that can be used individually, or together. The object is to reduce the ink film height as much as possible. Start by utilizing Grey Component Replacement (GCR) in your separations. Normally a range of 70-90% will yield satisfactory results. Couple this with a maximum ink coverage of 210%. Your separator will know what you are talking about (if he doesn't, find a new supplier!). The second is to utilize plain weave 355 (355 PW 34 micron thread) at a minimum of 25 N/cm. This will yield one of the thinnest ink deposits possible. The last resort is to clear coat between the second and third colors.

The clear coat can be done two ways. The simplest is to coat the entire design to smooth the surface. The better approach is to make a composite negative of the first two colors and print that in perfect register. This will fill in only the negative space between the dots and create the smoothest surface possible. It is much more difficult to achieve than a simple overcoat.

This should provide you with a basic understanding of the causes of moiré. It is a very complex issue on which we could spend considerable discussion. In concluding, there are several helpful suggestions that I might impart.

1. Don't panic. Be calm and work through your list to identify what type of moiré you have.
2. Hold your variables down as much as possible. This takes time, effort, and experience. Once you have it, results will be more consistent.
3. Look closely at everything. Use the loupe and microscopes to discover what is going on.
4. Record what you observe in a notebook or other reference source so that you can speed the elimination of causes in the future.

As I said at the beginning of this article, there are no total solutions to this challenge. Each job is different, and with careful attention you will be able to design a workable scenario for your shop and conditions.