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Close-Tolerance Printing

Maximize production without sacrificing image quality

By Mike Young, Member *Academy of Screen Printing Technology*

Developing an economical, productive printing process is the goal of any screen-printing company. And if your shop specializes in high-volume work, such as decals, labels, overlays, or similar small- and medium-format graphics, this goal is among the most critical. If this describes your operation, then you've probably discovered the obvious solution: using larger screens and ganging multiple duplicate images on them. After printing, you simply emboss, sheet, die cut, and/or finish the graphics other ways to complete the job.

This approach can work well for a number of applications. But as you continue to push the production-volume envelope, you eventually may find yourself limited by the size and configuration of your press. What you discover is that even when you use the maximum screen size the press will support, you can only use a portion of the screen for the image area. Exceeding this maximum image area inevitably causes image distortion, which can lead to registration problems between colors and make it impossible to accurately die-cut or otherwise finish the graphic.

Further complicating the situation is the fact that you may be relying on the press's guides for substrate positioning. If so, it's possible that you'll be tempted to offset the location of your images on the screen, positioning the graphics so that they will be centered on the substrate during printing. But as you'll discover, this can also lead to distortion problems and costly waste prints.

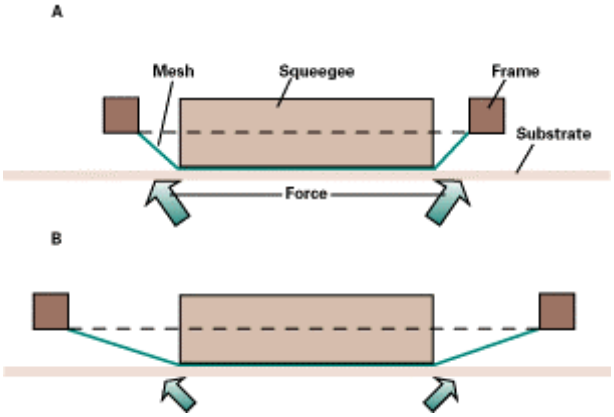
In this article, I'll look at the relationship between image size and screen size and the way this relationship can affect your success in close-tolerance printing applications. Additionally, I'll consider how the position of images on the screen can affect the quality of your finished graphics. Throughout this discussion, I'll focus on the way these factors come into play on four-post graphics presses using screens on which high tension levels are being maintained.

Image-to-frame ratio

Whether you're printing a single large image or multiple smaller images simultaneously, understanding the concept of ***image-to-frame ratio*** is critical for avoiding image distortion. This term refers to the size of the image area relative to the total screen area, which is usually represented by the frame's inside dimensions.

To illustrate the importance of the image-to-frame ratio, consider a tight-tolerance 20 x 30-in. image (or group of images). If you were to print the graphic on a press with a manufacturer-recommended maximum image area of 20 x 30 in., as well as on a press with a 30 x 40-in. maximum image size (using the largest frame size either press will support), the prints produced on the larger press would be far less likely to distort than those printed on the smaller press. While both machines are quite capable of printing up to their maximum image sizes, these sizes can be limiting, particularly if you're dealing with critical, tight-tolerance work.

The problem with the smaller press is that its screens provide less free mesh around the perimeter of the image area. Even with minimal off contact, the smaller screens require more squeegee pressure to bring the image into contact with the substrate. As a result, the mesh may be deflected more than desired and cause distortion of the images (***Figure 1A***).



Figures 1A and 1B: Screen Deflection
These illustrations show that the less a screen is deflected during the print stroke, the lower the force against the mesh and the lower the possibility of distorting the printed image. For images of the same size, a smaller screen (A) will deflect more and produce greater distortion than a larger screen (B).

On the larger press, the greater screen size leads to more free space around the image areas. And because the larger press provides more free mesh area, when the squeegee passes across the screen, it causes less deflection and image distortion (***Figure 1B***). The result is a printed image that is more likely to fall within your desired tolerances.

One of the most popular approaches to figuring maximum image size is known as the "eight and six rule." This rule maintains that a fixed measurement should always be used for image placement on the screen. The image should be positioned a least 8 in. from the frame edge where the squeegee stroke begins and a minimum of 6 in. from either of the frame sides. In many cases, this rule will serve you well. But some applications may require even more free mesh area at the edges to ensure accurate, distortion-free images.

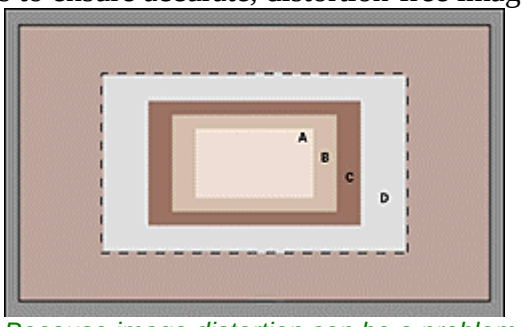


Fig. 2: Ideal image-to-frame ratios for specific applications.
Ideal image ratio to useable "free" fabric area are:
A = Printed circuits <25%
B = High quality and close tolerance < 35%
C = Quality graphics < 45%
D = Typical max stated by OEMs ~55-65%

Because image distortion can be a problem on close-tolerance work, you should strive to keep your image-to-frame ratio as low as possible on such jobs. This illustration depicts suitable ratios for common close-tolerance applications, as well as the maximum ratios recommended by manufacturers.

In my experience with equipment manufacturing and consulting, I've recorded successful and unsuccessful image-to-frame ratios for specific applications. Based on this information, I've developed the following list of guidelines to help steer you to appropriate screen/image sizes (***Figure 2***).

- **For printed circuits, no more than 25% of the total mesh area should be used for the image.**
- **For close tolerance (e.g., decal, label), printing the image should take up no more than 35% of the mesh's total area.**
- **For quality process-color display graphics, no more than 45% of the total mesh area should be taken up by the image.**

With most presses, using the manufacturer-recommended maximum image size with the largest frame the press supports will give you an image-to-frame ratio of 55-65%--far in excess of the values recommended for any quality graphics work, especially close-tolerance jobs.

Let's review two scenarios for printing the same critical job, but on two different substrate and press sizes. Job A is an 18 x 26-in. image and job B is a 26 x 36-in., two-up version of the same image. The jobs are printed on presses with respective maximum images sizes of 20 x 30-inch and 30 x 40-inch. Figure 3 details important measurements and image-to-frame ratio values for these jobs, and as you can see, job A enjoys an acceptable image-to-frame ratio of 35%, while job B has a rather unhealthy 45% ratio. Even though job B has twice the overall print area of job A, its image-to-frame ratio is dramatically different.

Fig. 3: Sample Job Comparisons
This table compares two jobs involving the same image that were printed on presses with different maximum screen and image sizes. Note that if the image is offset, the resulting "equivalent image-to-frame ratio" rises sharply.

	Job A	Job B
Max print size	20 x 30 in.	30 x 40 in.
Inside dimensions of frame (maximum size)	35 x 38 in.	42 x 50 in.
Image size	18 x 26 in.	26 x 36 in.
Image clearance to top frame edge[1]	8.5 in.	8 in.
Image clearance to frame sides	6 in.	7 in.
Image-to-frame ratio (image centered)	35%	45%
Image clearance to top frame edge (image offset)	5.5 in.	5.5 in.
Image clearance to frame sides (image offset)	6 in.	6 in.
Equivalent image-to-frame ratio when image is offset	47%	56%

[1] Top frame edge refers to the side of the frame parallel with the squeegee/floodbar assembly. Frame sides are the edges parallel with the squeegee stroke.

Squeegee length also figures into the relationship between image size and total mesh area. As a general rule, it's usually not a good idea to use squeegees that exceed the width of the image area by only about 1 in. on both sides. If you use squeegees that greatly exceed the width of the image, you cancel out the positive effects of free space around the image area. In other words, the squeegee still approaches the edges of the frame and leads to the mesh deflection and subsequent image distortion that you're trying to avoid.

Image positioning on screen

In graphics screen-printing worldwide, the main workhorse is the four-post flatbed press, either in three-quarter-automatic models (which have integrated takeoff systems) or semiautomatic models (where sheets are manually loaded and unloaded). Regardless of the specific press model, one characteristic which all three-quarter-- automatic and most semiautomatic presses share is that they incorporate a series of mechanical edge guides that raise and lower between print strokes to ensure accurate substrate placement.

The typical layout of the press bed on these machines positions a row of guides at the side of the bed farthest from the loading position (which I'll call the back of the bed) and single guides along both the left and right sides of the bed (***Figure 4***). The guides along the back of the press bed serve as the machine's "gripper datum line," the point where mechanical takeoff devices can grab the sheet and move it on to the next print or finishing station.

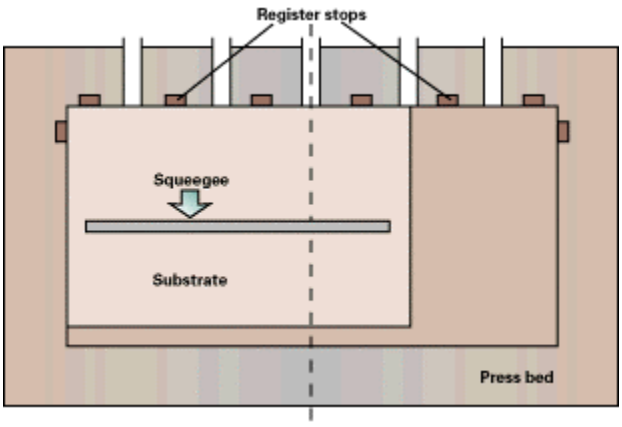


Fig. 4: Register Guides
Most three-quarter- and semiautomatic four-post graphic presses incorporate mechanical register guides on three sides for substrate positioning. With images and substrates that are smaller than the maximum sheet size the press bed will support, the sheets are normally positioned against the register guides at the back and on the left of the press bed. But this means the image must be offset on the screen to print at the proper location on the sheet, and the offsetting can lead to image distortion. The best solution in such situations is to center the images on your screens and establish a temporary registration edge guide for substrate positioning.

When working with substrates that are smaller than the maximum sheet size defined by the position of the press's register guides, it's common practice to position the substrate against the back and left guides. If these guides are used, it's also common for printers to offset the stencil image on the screen so that the printed image is correctly aligned with the substrate.

For many applications, particularly those involving single, large images with non-critical tolerances, positioning the image on one side of a screen does not present a problem. However, it can be an entirely different story for tight-tolerance applications, especially when the screen features multiple images that will be die cut.

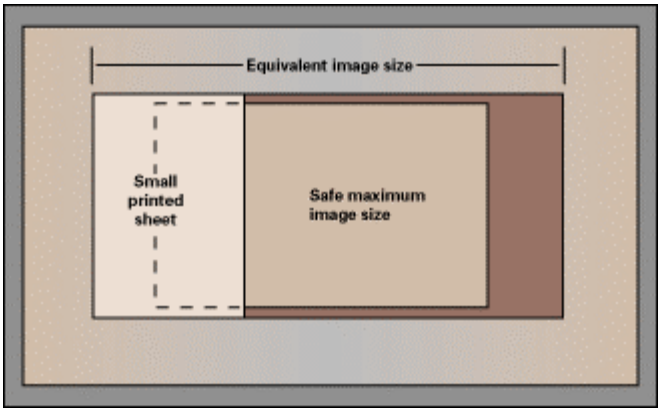


Fig. 5: Equivalent image-to-frame ratio
If an image is offset on a screen, its image-to-frame ratio is actually higher than its size would indicate. Consequently, offset images are more likely to cause distortion problems.

The position of the image on the screen influences the apparent image-to-frame ratio. Although the centered and offset images take up the same area relative to the total screen area, offsetting the images actually makes the press behave as if it's printing a larger image (***Figure 5***). This principle is further demonstrated by the example jobs in Figure 3, where the "equivalent" image-to-frame ratio after offsetting the images increases substantially--up to 47% on job A and 53% on job B.

To calculate the equivalent image-to-frame ratio, use the offset image position to define the image-to-frame distance at the back edge and along the side closest to the substrate register stops. Double these distances and subtract them from the frame's inside dimensions to get the "equivalent size" of the image area. Using job A as an example, your calculation would be (35-(2 x 5.5)) x (38 - (2 x 6)) = (35-11) x (38 - 12) = 24 x 26 = 624 sq in. If you divide this value by the frame's inside dimensions (35 x 38 = 1330 sq in.), you get 624/1330 x 100% = 47%. Basically, these calculations tell you that in terms of distortion, an 18 x 26-in. image offset with a top image-to-frame distance of 5.5 in. and a side distance of 6 in. is equivalent to a centered image that measures 24 x 26 in.

Also consider the squeegee's influence if you're offsetting images on the screen. Assuming the squeegee is only slightly larger than the image area as recommended previously, the result will once again be an uneven deflection of the screen.

The principle involved here is that the force of the squeegee is distributed equally over the entire mesh area, resulting in some elongation of the mesh threads. However, since the offset graphic is typically aligned by positioning one edge of the stencil image (usually the edge nearest the press' side register guide), the screen deflection and subsequent printed image distortion are more pronounced along the opposite side of the image (***Figure 6***).

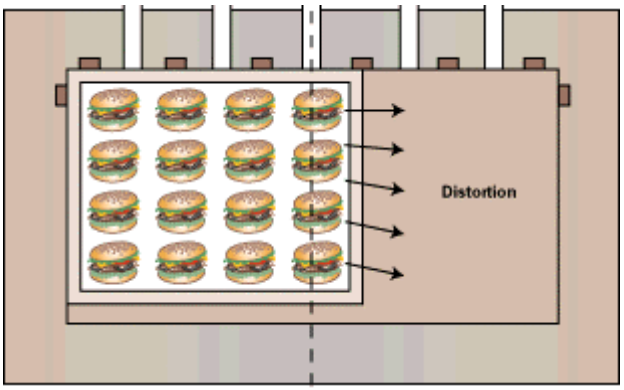


Fig. 6: Free-mesh area and distortion
Mesh threads will elongate a specific distance per inch (which varies with mesh type, count, brand, and tension level) in response to squeegee pressure. Because of this, the image distortion that results from screens with offset images is most pronounced at the image edge nearest to the screen's free mesh area.

Depending on the specific design of your press and the size of your image, it may be impossible to avoid offsetting images on screens, particularly on three-quarter-automatic presses where you must position substrates against register stops to ensure that take-up mechanisms can grab the materials. But you still may be able to center the images if you can print multiple images with the same screen and approach the maximum image size for your application as recommended in Figure 3.

If your press requires manual unloading of sheets, you're even less restricted. With such presses, you can establish your own substrate positioning guides and always center your images on screens, thereby avoiding the distortion issues associated with offsetting images. Additionally, you'll have the flexibility to use a wider range of screen sizes, provided that they meet the image-to-frame ratio requirements of the job.

Conclusion

Satisfying demanding printing and finishing tolerances while maximizing productivity is not always simple. To achieve these goals successfully, you need to understand how image size and position relative to the screen influence the characteristics of the printed image.

Depending on the nature of the job you're printing and the tolerance requirements you have to meet, you may have to limit image area to 45% or less of your total mesh area. Additionally, while the specific characteristics of your press will influence where you position images on screens, your safest bet is always to attempt to center the images. By following these general guidelines, you'll go a long way in alleviating image distortion problems.

ASPT Member Biography

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Inducted into the Academy in 1997

Mike Young has been a specialist in graphic and industrial screen printing for more than 30 years. He is an SGIA Fellow and a member of the ASPT (Academy of Screen Printing Technology), as well as being a recipient of the prestigious Swormstedt Award for technical writing. As a frequent contributing writer to trade publications and a popular speaker at industry events, he has published his own technical books on advance screen printing techniques. Mike is former Chair of the SGIA Membrane Switch Division and now the President of Dekalb, Texas-based Liberty International Technology Inc – manufacturers and suppliers of sophisticated screen printing equipment. Mike currently owns and operates Imagetek, North Haven, CT, a screen-printing consulting business.

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