IMPROVING SOLDER PASTE PRINTING WITH SQUIRCLE APERTURE DESIGNS

BY TIMOTHY O'NEILL AND KARL SEELIG

BASED ON THE ARTICLE "SQUARING THE CIRCLE" ORIGINALLY PUBLISHED IN CIRCUITS ASSEMBLY

The term "squircle" is a portmanteau, or mashup, of "square" and "circle". It looks like a square with rounded corners. Mathematically, this shape is known as a superellipse. When it comes to SMT stencil design, a looser definition is often used, and the actual shape is known as a rounded square - generated by separating four quadrants of a circle and connecting them with a straight line.

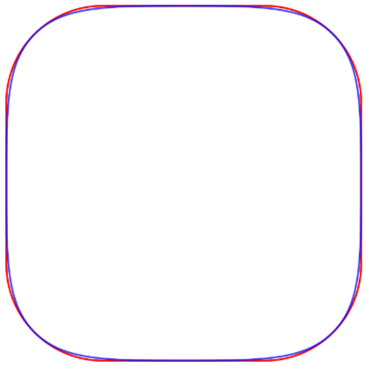

Figure 1. Superellipse(blue)≠rounded square(red), but the shapes are similar and may both be referred to as a "squircle".

As it turns out, the squircle is an effective shape for maximizing both solder paste volume in tight spaces, and improving transfer efficiency.

The Properties of Squircle Apertures

The squircle design incorporates the positive features of both circle and square apertures.

Circle Aperture Features

Because of their smooth, rounded design, circle apertures have no pad-overlapping corners and no paste dead zones. But it is much more difficult to get sufficient paste volume in tight spaces using circles. This is because the area of a circle with a given diameter is less than that of a square with the same side length (using formulas for the area of a circle vs area of a square: $\frac{\pi}{4}d^2 < d^2$).

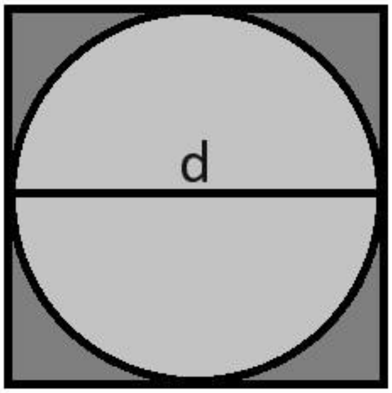

Figure 2. The area of a square of side length d is greater than the area of a circle of diameter d.

Additionally, circles have equal surface tension across the diameter of the aperture. During separation, this may increase the amount of solder paste that remains in the aperture. Imagine a soap bubble on a flat surface; equal surface tension keeps it stable. This same characteristic discourages paste from exiting the circular aperture.

Square Aperture Features

A square has the inherent benefit of maximizing paste volume in tight spaces. When printing solder paste, however, the particles tend to agglomerate in the sharp aperture corners, resulting in more variation from deposit to deposit. It is also likely this variation will grow over time if the stencil wipe efficacy diminishes and the paste accumulation increases.

Squares inherently have larger surface areas than circles of the same major dimension, so they should deposit more paste, but if those paste-grabbing corners overlap pad edges, they also create gasketing problems that can further drive high variation.

Squircle Apertures

The squircle combines the volumetric benefit of square apertures with the paste release benefits of rounded shapes, which also avoids regions of paste accumulation. It brings the best of both worlds to an extremely challenging part of the printing process.

Experimental Comparison of Aperture Shapes

Extensive print testing at AIM's Juarez, Mexico, applications laboratory, using a stencil containing square, circle, and squircle aperture shapes, supports the strong case for the squircle as a solution to many print challenges. By testing apertures of the same major dimension (diameter or side length) and similar area ratios, we were able to directly compare transfer efficiencies and actual deposit volumes.

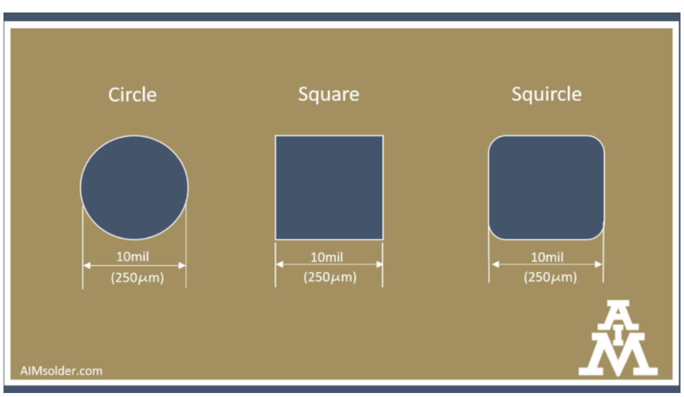

Figure 3. Aperture shapes tested for transfer efficiency, variation, and deposit volume.

FIGURE 4 shows the measured transfer efficiencies and calculated coefficients of variation of each type of aperture. Notice the transfer efficiency is slightly lower on the square than the circle, but only by a few percentage points. The square also has slightly higher variation with the Type 4 paste and is equivalent to the Type 5 paste data. The squircle consistently has the highest transfer rate, and comparable or lower variation than the squares or circles.

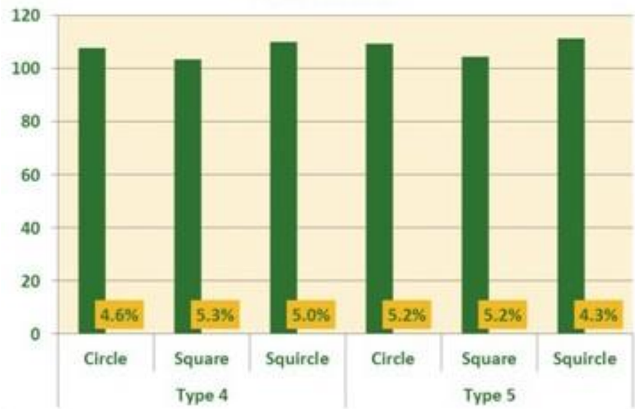

Figure 4. Transfer efficiency and coefficient of variation for different aperture geometries with area ratios of approximately 0.63.

FIGURE 5 shows the average volume deposited by each aperture shape. Note that although the square showed lower transfer efficiency, its larger area resulted in higher volumes than the circle. But the squircle deposited the highest volumes of all apertures. In all cases, the Type 5 paste consistently produced marginally higher volumes, but not enough to justify a transition to it in a production environment where cost, separate storage, and reflow issues would arise.

Figure 5. Deposit volumes for different aperture geometries.

Final Notes

It’s important to note that in these experiments transfer rates are very high and variation rates very low compared to typical results from similar print tests. These print tests were conducted under an ideal environment, using a polymer nanocoated stencil. It is reasonable to expect similar trends in production environments, but with lower transfer rates and higher variation rates. It is also reasonable to consider using nanocoatings on stencils with tight area ratios because of the (frequently documented) quality improvements they provide.

Data collected, but not shown here, also indicate the squircle is more robust against the effects of room-temperature aging and long pause times (>60 min.) between prints.

While our study underscores the squircle's potential, further research is warranted to explore its applications across diverse assembly conditions and materials. Nonetheless, the initial results are promising, positioning squircles as a viable enhancement to stencil design practices.