

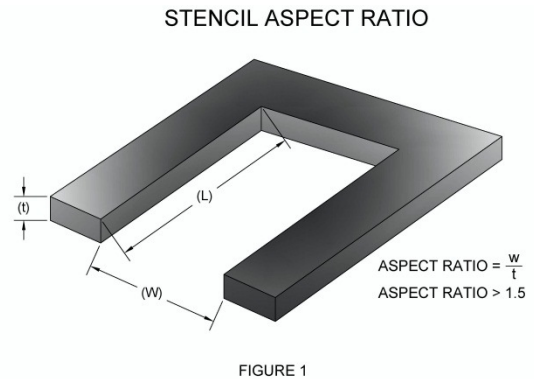
Successful Stencil Printing: Performance is on the Surface

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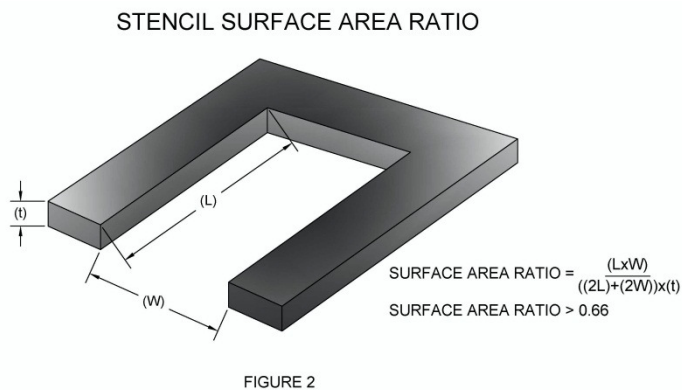
The introduction of the metal solder paste stencil, decades ago, to the SMT assembly process was a revolutionary change in electronics production. Wire mesh screens were the standard before then and the physics of pushing solder paste through a wire mesh severely limited aperture sizes, print volume consistency, stencil longevity, and print speed. The metal solder paste stencil dramatically improved upon all of these deficiencies.

There have been many changes to metal solder paste stencil manufacturing over the years that have contributed greatly to the miniature assemblies we see today. SMT assembly throughput and efficiency have been increased as well as product reliability. However, determining the potential print performance of metal solder paste stencils has not really changed much at all.

The most common method of determining stencil print performance for a given foil thickness has been to calculate the *aspect ratio* of the smallest stencil aperture (see figure 1). It compares the smallest dimension of the stencil aperture to the thickness of the metal foil. Typically, the lowest acceptable aspect ratio is 1.5. However, advancements in stencil manufacturing technology and materials can make aspect ratios lower than 1.5 possible.



While aspect ratio is a valid determination of potential stencil performance, it is limited to simple shapes like squares, rectangles, and circles. A more accurate, and more detailed, method of determining



potential stencil print performance is the *surface area ratio* (see figure 2). Again, it should be applied to the smallest stencil aperture. However, it can be used on any stencil aperture regardless of the shape. It compares the surface area of the stencil aperture ($L \times W$) to the surface area of the stencil aperture walls $((2L) + (2W)) \times (t)$. Typically, the lowest acceptable surface area ratio is 0.66. However, advancements in

stencil manufacturing technology and materials can make lower surface area ratios possible. Some stencil suppliers can provide stencils that print extremely well below a surface area ratio of 0.5.

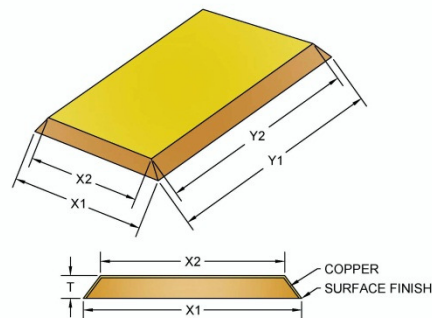
Both the aspect ratio and the surface area ratio are valuable formulas to use. They can help greatly in reducing some printing problems. However, component SMT pad sizes keep getting smaller and

smaller. Is there anything better to use to more accurately predict stencil print performance? The answer is *yes*.

The stencil aspect ratio and stencil surface area ratio only consider the stencil thickness and stencil aperture size when predicting print performance. The printed circuit board (PCB) is not considered as a factor. However, the size of the SMT pad on the PCB determines the adhesion strength between the solder paste and SMT pad and is extremely important now that miniature components are becoming more main stream. SMT pad sizes will differ from the pad sizes in the electronic PCB files based on the pre-finished copper weights and surface finishes.

Printed circuit boards typically have a pre-finished copper weight of 0.5 oz, 1.0 oz, or 2.0 oz on the outer layers. The PCB manufacturing process consists of etching the copper to produce the circuitry (traces, SMT pads, via pads, etc.). The copper etching process will produce a trapezoidal cross section (see figure 3) where the top of the SMT pad will be smaller than the bottom. In most cases, the bottom of the SMT pad will match the size in the electronic PCB files since the bottom dimension is critical in meeting impedance requirements for the circuitry. The top of the SMT will be smaller because of the copper etching process (the size reductions can vary between PCB suppliers, but the reductions shown in figure 3 are typical). The smaller top size must be used in determining the stencil surface area since the adhesion of the solder paste to the SMT pad is what pulls the solder paste from the stencil. As previously mentioned, the size of the SMT pad on the PCB determines the adhesion strength between the solder paste and SMT pad.

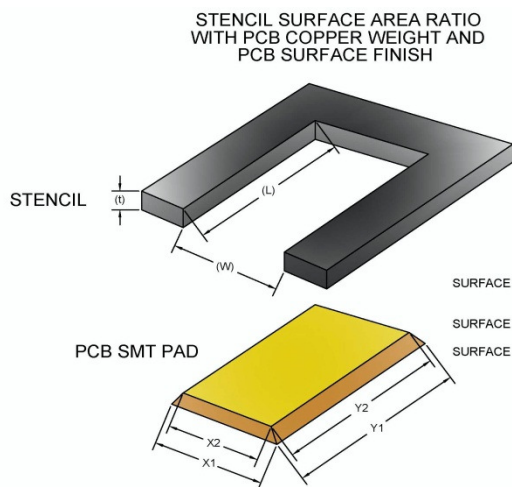
PCB SMT PAD SIZE CHANGES DUE TO COPPER WEIGHT AND SURFACE FINISH



COPPER WEIGHT	THICKNESS (T)	TYPICAL REDUCTION	TOP SIZE (X2 & Y2) ENIG, OSP, Ag, & Sn	TOP SIZE (X2 & Y2) HASL
0.5 OZ	17.5 um	0.002"	X1-0.002" Y1-0.002"	X1-0.004" Y1-0.004"
1.0 OZ	35.0 um	0.003"	X1-0.003" Y1-0.003"	X1-0.005" Y1-0.005"
2.0 OZ	70.0 um	0.004"	X1-0.004" Y1-0.004"	X1-0.006" Y1-0.006"

FIGURE 3

The most accurate method of determining potential stencil print performance is a modified surface area ratio formula that compares the surface area of the SMT pad (at the top) and the surface area of the



$$\text{SURFACE AREA RATIO} = \frac{\text{SMT PAD SURFACE AREA}}{\text{STENCIL APERTURE WALL SURFACE AREA}}$$

$$\text{SURFACE AREA RATIO} = \frac{(X2) \times (Y2)}{((2L) + (2W)) \times (t)}$$

$$\text{SURFACE AREA RATIO} > 0.66$$

FIGURE 4

stencil aperture walls (see figure 4). This comparison takes into account changes in the PCB SMT pad sizes, based on copper weight and surface finish. Heavier copper weights will have a larger size difference between the top

and bottom of the SMT pads. ENIG, OSP, immersion Ag, and immersion Sn surface finishes are flat and allow the solder paste to stick to the entire top surface of the SMT pad. A HASL surface finish has more of a domed finish and the semi-rounded surface makes it more difficult for the solder paste to stick to the entire surface. This will reduce the adhesion strength between the solder paste and SMT pad. Heavier copper boards, and those with HASL surface finishes, will present the most print challenges when miniature components are present.

Stencil aperture sizes have been increased many times with the expectation that a larger stencil aperture size increases the surface area ratio. In many of those cases, solder paste release was not improved and this is due to the fact that the size of the SMT pad, and the corresponding adhesion strength between the solder paste and SMT pad, did not change.

However, there are times when increasing the stencil aperture size can help. As long as the modified surface area ratio passes, the benefit of a larger stencil aperture size is a wider alignment tolerance between the stencil and PCB at the printer. The wider alignment tolerance increases the process window at the printer and can increase assembly yields.

While the standard aspect ratio and surface area ratio calculations have been a very good determination of stencil print performance, they do not consider the printed circuit board. Components are getting small enough now that the printed circuit board, its copper weight and surface finish, has to be an important part of determining stencil print performance.