模版差异源于设备差错和人为干扰。本研究说明一个控制差异的系统，从而改善模版印刷产量并缩短工程时间。严格控制承包商用光圈表的初始设备制造商可使用这个系统将其光圈应用于数据文件，即使承包商已在向模版制造商提交前在当地做过修改。或者，这些制造商可得到以前在别处用过的模版，省去两个转移步骤。面对初始设备制造商的多种设计规则的CEM可自动管理这些设计规则，从而腾出工程时间。

Reducing Variation Through 'Intelligent' Stencils

Chrys Shea, Valentijn Van Velthoven, Ron Tripp and Ranjit Pandher

A study on stencil design and manufacturing and its impact on printing.

Since the object of stencil printing is the repeatable deposition of the proper amount of solder in the proper location, the factors that affect aperture size and aperture location must be explored. The majority of stencils currently used in surface-mount assembly are produced by laser cutting apertures from metal foils. Many factors affect the accuracy of the position and size of the apertures. Standard equipment considerations include machine type, wear, maintenance, calibration and age of the laser lamp. Also, because stencil foil is so thin, it responds rapidly to changes in temperature and tension during the cutting process. A 5°F change in operating temperature is sufficient to cause a 0.001" change in a stencil's positional accuracy over 20". A similar change is also seen if the foil tension is not the same in the cutting machine and the stencil's frame.[1]

Aperture size is critical to depositing the proper amount of paste. The considerations on aperture size are area ratio (AR) and transfer efficiency (TE). Area ratio is defined as the area of the circuit-side opening of the stencil divided by the area of the aperture walls. The ratio is important because solder paste adheres to any surface it contacts, and the surface tension holding paste to the lands must overcome the surface tension holding paste to the aperture walls for the paste to release. Transfer efficiency is calculated as the volume of paste actually deposited divided by the volume of the stencil aperture, and is expressed as a percent.

For area ratios less than 0.7, transfer efficiency can be modeled as (**Figure 1**):

$$TE = 100 \times (2.404 \times AR^{3.426})$$

Statistical analysis of the study that produced this model showed that for given solder paste and print parameters, 95% of transfer efficiency depends on area ratio. Other factors, such as degree of taper and electropolish, contributed 5%. It was also found that as the area ratio increased, the standard deviation of transfer efficiency decreased. The study was performed using

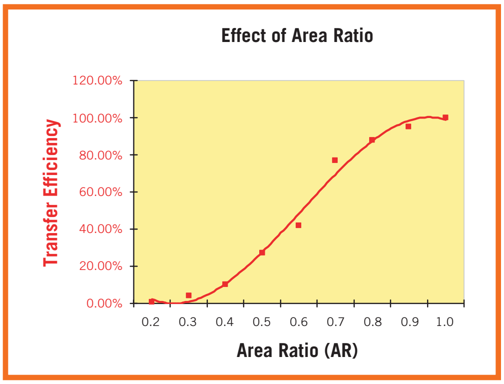
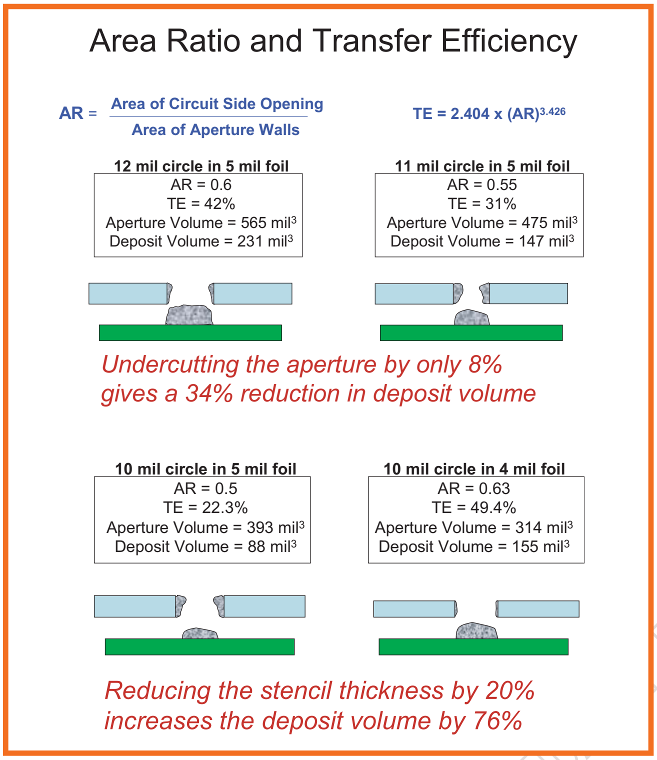


FIGURE 1: Plot of transfer efficiency vs. area ratio. Notice the relationships in the 0.5 to 0.7 range, which encompass feature sizes from 0.010 to 0.014". Typically, as transfer efficiency decreases, variation in the volumes of the deposits increases. This is a function of absolute aperture volume.



28FIGURE 2: Effect of undersizing fine feature apertures and stencil thickness on paste deposit volume.

Sigma Level	Cpk	PPM Defective	Defects / 5000 Aps
1.00	0.33	158700	**793.5**
1.50	0.50	66800	**334.0**
2.00	0.67	22800	**1114.0**
2.50	0.83	6200	**31.0**
3.00	1.00	1350	**6.8**
4.00	1.33	32	**0.2**
4.5	1.50	3.4	**0.0**
5.00	1.67	0.3	**0.0**
6.00	**2.00**	**0.001**	**0.0**

** To positional accuracy of ±0.001". Note: PPM Defective is based on a static process, and does not include the 1.5 sigma shift.*

TABLE 1: Correlation of process capability*.

a single type 3, no-clean solder paste. It is expected that other pastes can be similarly modeled.

In some cases, paste deposit volume and repeatability can be dramatically increased by decreasing stencil thickness. Given that area ratio is the dominant factor in release mechanics, options to optimize the area ratio must be considered. Recall that the denominator of the area ratio is the area of the aperture walls. By using a thinner foil, the area of the walls decreases, thereby increasing the ratio and increasing transfer efficiency. **Figure 2** illustrates the importance of size accuracy and the effect of stencil thickness.

Another source of variation that must be addressed is positional accuracy of the apertures. Paste must be deposited at the proper location. If it is not aligned with the pad, then solder bridges, solder balls or insufficient solder may result. The situation is exacerbated by lead-free solders that do not have the same propensity to spread as lead-bearing materials.

To control positional accuracy, the stencil manufacturer must characterize its laser cutters and calibrate them using offsets learned through the characterization process. One method of characterization is to design a standard test vehicle, cut it, and measure the variation from CAD data, or nominal position. The test vehicle currently used for laser calibration at Cookson Electronics is comprised of 324 identical circular apertures set on 1" centers over a 17 x 17" grid. After cutting and measuring, the data are analyzed for linear drift along the length of the machine axes and for angular displacement. The results of the analysis are then used to incorporate correction factors to ensure that positional accuracy is held to 0.001" at 4 sigma levels, or a Cpk of 1.33.

Mapping the positional accuracy of a laser cutter by measuring the finished test vehicle reveals interesting results. **Figures 3 and 4** compare the x positional accuracy of a laser cutter before and after calibration. Similar shift is observed in the y direction as well.

Aligning the Stencil and PCB

Several sources affecting stencil/PCB alignment include the variation of the positional accuracy of the board, variation of the alignment capability of the printer, and variation in the stencil itself.[2] If stencil variation is contained, and the variation of a calibrated printer is known to be +/- 0.001" at 6 sigma[3], then the remaining factor is the positional accuracy of the PCB itself. Board variation is by far the largest contributor to misalignment. PCBs are known to "shrink" from CAD data, a result of the fabrication process. They also experience some shrink during the first reflow, exacerbating misalignment when printing the second side of the board. Variation in the PCB can

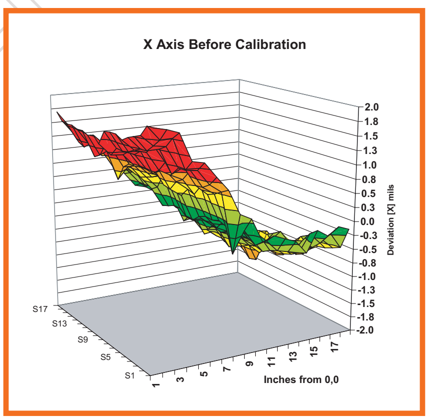


FIGURE 3: Positional accuracy map of uncalibrated x axis.

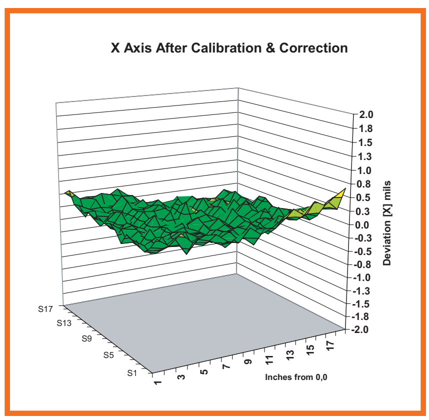


FIGURE 4: Positional accuracy map of x axis after calibration.

be measured so that a stencil can be generated to custom-fit the PCBs.

However, stencil design still needs to be controlled. Aperture design has been shown to be critical to paste transfer. Some companies have standard aperture libraries, while others rely on site preferences or the preferences of individual engineers or departments for aperture design.

A standard library can result in easier yield data interpretation, faster troubleshooting, minimized learning curves and smoother product transfers. The difficulties encountered when standardizing include determining the standard aperture geometry, controlling and communicating changes, enforcing application of the standards, and suboptimizing processes that are sensitive to their environment.

Standardizing and managing stencil design data can be automated by a system that uses an intelligent database to apply design rules to stencil data files. The system reads Gerber files and recognizes components.[4] It then queries one or more databases for design rules that apply to each component. The order of the databases can be set according to the application. If an assembler has a universal aperture library, the system will query only that database. If a particular site has individual preferences for certain components or in response to particular environmental conditions, design rules for that site would then be applied. The hierarchy for database application can continue. Rules for different types of pastes or experimental apertures for data collection purposes could be applied. Aperture lists for direct pressure print heads or squeegee blades could also be applied. The power of relational database management can be exploited to suit a limitless variety of configurations.

Some benefits of intelligently managing stencils are universal; other benefits can have greater or lesser impact, depending on the technical relationship between OEM and CM.

Minimizing stencil variation in any region of the world benefits global manufacturers when transitioning production between facilities. Managing data in a centralized system also offers a variety of options related to security, controls and flexibility.

An OEM that strictly controls aperture libraries for their contractors can use the system to apply its apertures to the Gerber file, even if it has been modified locally by the contractor prior to submission to the stencil manufacturer. Alternatively, it can request that its contractor order exact duplicates of stencils previously manufactured for assembly at a different site, eliminating the need to transfer Gerber files to the contractor, and then on to the stencil manufacturer.

A CM that deals with a multitude of design rules from OEMs can have those design rules automatically managed, thereby freeing up engineering time.

CMs that manage their own optimum aperture libraries repeatedly invest time in applying their design rules to all new jobs. Managing the rules intelligently requires a one-time manpower investment to set design rules in the system, but eliminates the repeated cost of applying the rules to every new job.

References

1. I. Fleck and P. Chouta, "A New Dimension in Stencil Print Optimization," *SMTA International Proceedings*, September 2002.
2. D. Mendez and R. Clarke, "Statistical Model of Printed Wiring Board and Stencil Alignment Issues," *Surface Mount International Proceedings*, April 1997.
3. Eagle-Eyed One, an independent engineering firm that characterizes stencil printer performance.
4. AlphaDimensions, Cookson Electronics Assembly Materials.

Ed.: This article was first published at SMTA International 2003 and is used with permission.

***Chrys Shea** is an applications engineering manager, **Valentijn Van Velthoven** is a product manager, **Ron Tripp** is a quality engineer and **Ranjit Pandher** is a senior scientist at Cookson Electronics Assembly Materials (cooksonelectronics .com). Contact Shea at cshea@cooksonelectronics.com.*