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REPORT ON RESEACH TO IMPROVE STENCIL PRINTER THROUGH-PUT

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ABSTRACT

The complex stencil printing process is at the heart of today's SMT production. With more than 39 variables to optimize in the printing process, it's no surprise that between 50% and 90% of all the defects in SMT production originate on the stencil printer, according to some industry experts. Oddly, very few experts have considered the paper used in stencil wiping as an important variable in the printing process. Recent research by DuPont has proven this oversight to be a costly mistake. Their research suggests SMT printers can produce significant improvements in yield simply by changing the stencil roll paper. This technical note will compare the three most popular types of stencil rolls and suggest areas of improvement.

Keywords: stencil printing, solder paste, printing, lead-free solder paste, fine-pitch surface mount processes

INTRODUCTION

In today's world, it's hard to survive without making assumptions. Just as computerized "data compression" programs like "ZIP", "STUFFIT" and "JPEG" make files smaller and more manageable, humans use brand names, political parties, logos, "trusted sources" and assumptions to minimize the brain-strain about new people, products and events.

But in both computers and people, an unwanted side effect of data compression is data loss. JPEG compression routines, for example, simply discard redundant information in photographs but repeated compressions can inflict perceptible damage to the image. The same sort of data loss happens in human compression schemes, too. Every time we label a person or a thing – "she's a liberal" or "their products are no good" – we willingly accept a certain amount of fuzziness in the assertion. Taken to extremes, our assumptions turn into “blind spots.” Blind spots are assumptions made so widely, so often and usually so successfully that they become a perceived truth.

The worst aspect of blinds spots, of course, is their invisibility. Everybody has them but we can’t see them. We’ve habituated ourselves to the assumptions we made and forgotten the information being lost. This means that when circumstances change but the assumptions do not the potential for error jumps.

Recent research at DuPont has highlighted a stunning blind spot across the entire SMT industry. Everyone seems to assume that all stencil wipes are the same.

INTO THE LAB

DuPont is, of course, a giant company. Having just celebrated it’s 200th birthday, it has 55,000 technical specialists in seventy different countries. Their scientists generate an average of 1,000 patents annually. And, among other things, DuPont makes the paper used in stencil rolls. DuPont’s “Sontara®” material has been the benchmark of SMT production since the first days of stencil printing in 1985. While Sontara® fabrics are no longer alone in the market, they certainly remain a leader.

But the Sontara® product team saw signs that stencil wipes were not keeping up with the advances in SMT assembly. Anecdotal evidence accumulated about falling yields, problematic solder joints, and problems with lead-free pastes. So Senior Researcher Dr. Kim Abbett from the Sontara® laboratories was asked to review the situation. Her job was to determine if there was a problem and, if so, to find a new fabric to solve it.

Photo; left: Dr. Abbett and her daughter, Libby.

It was a tough assignment because stencil printing is an intricate balance of technologies. Process engineers must optimize as many as 39 different processes to obtain profitable yields [Note 1]. Several industry experts have estimated as many as 50-60% of all the SMT defects stem from the stencil printing process [Notes 2, 3], and in a private conversation another insider estimated the real number to be closer to 90%. The goal is clear: fixing the stencil printing process should fix the entire SMT line.

In the DuPont fiber lab Dr. Abbett assembled a wide array of synthetic and natural fibers for testing. In general, there are two types of papers used in stencil wiping: papers made with synthetic fibers which are held together with glues (called “binders” in the paper trade) and papers made with a mix of natural and synthetic fibers which do not use glues.

The synthetic fibers found in paper are usually polyester or rayon. In general, about 30% of this paper’s weight is in binders. In general, these papers have a harder surface, have lower tensile strength, absorb less contamination and are generally less expensive than their glue-less counterparts.

The original Sontara® wipes are made with a process called “hydroentangling.” The process involves laying raw fibers of polyester and cellulose on a conveyor belt and intertwining the fibers with high-pressure jets of water. Heat and pressure are then used to dry the slurry into the proper configuration. Lacking glues, hydroentangled papers have a softer feel. They are generally more absorbent, thicker, and stronger than ordinary paper.

Dr. Abbett’s new material is a hydroentangled, single-fiber polymer based on regenerated cellulose. Totally synthetic, the fabric contains no natural fibers and no binders. Under a microscope, the long, thin, hard fibers are identical and homogenous, giving the fabric an open structure. The material is a pale off-white color, almost fluffy and highly absorbent. The fabric scores very well on the solder paste pick-up test for non-liquid contamination (see Sidebar).

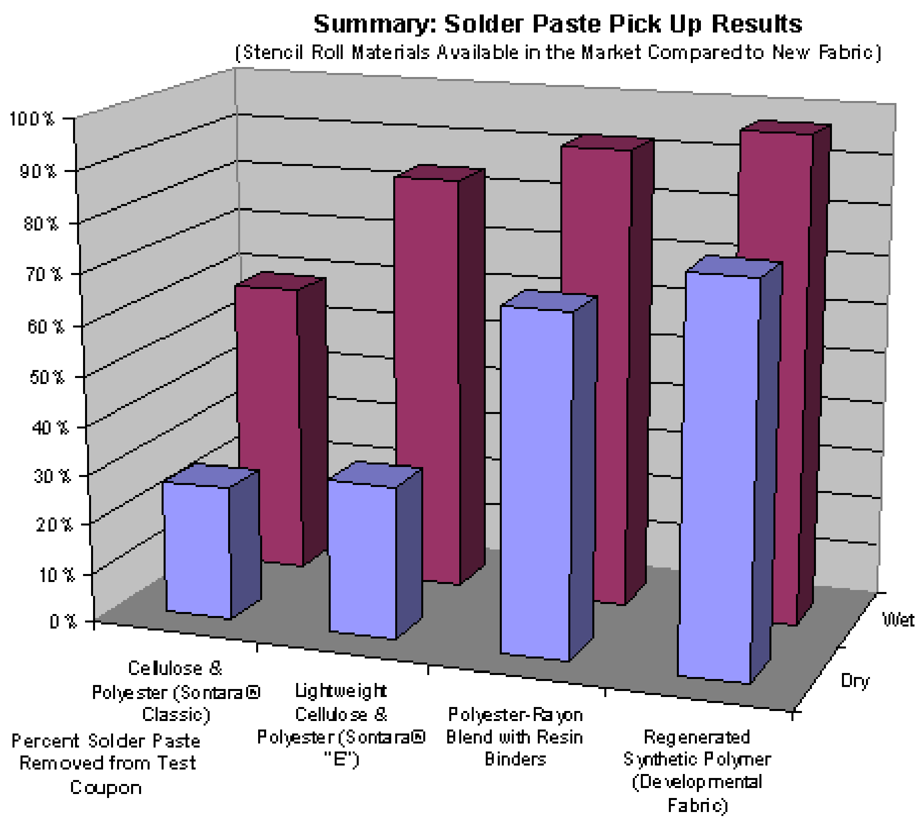
All of the potential fabrics were tested; a few typical results are presented in Table 1 (below). Dr. Abbett was able to decisively answer two questions. First, she proved there was substantial variation in the ability of different fabrics to remove solder paste. Her second conclusion determined that one fabric was able to consistently out-clean and out-perform any other tested fabric (at least, in the lab). But how would it work in the field? It was time to take her show on the road.

FIELD TRIAL HEADACHES

The problem was few of the engineers Dr. Abbett contacted were interested in testing new stencil wipes. They were eager to test new printers, new squeegees, new solder pastes and new stencil designs. But there was great resistance to testing new stencil rolls. Their replies were all variations of the same theme: “All stencil rolls are pretty much the same,” “the stencil roll isn’t a source of variation in the process,” and “the best stencil roll is the cheapest stencil roll.” Obviously, there’s not much point to testing a new stencil roll if the stencil roll doesn’t make a difference.

Dr. Abbett had run smack into the industry’s blindspot.

Like a virus, this blindspot had infected the entire SMT industry. At the urging of Dr. Abbett, the author undertook a review of English-language technical papers published since 1994 involving stencil printing. Amazingly, *not one paper* out of the 351 reviewed suggested that the stencil roll might be a source of improved yields, enhanced throughput or reduced costs. Even as recently as January 2005 one industry expert dismissed Dr. Abbett's research saying, "I doubt that changing the paper will have much effect on printing quality."



While it took almos two years, Dr. Abbe found a few engin willin to test the new fabric More than 1,000 stenci rolls were consumed in long, grueling field trials in the U.S., Mexico and Europe.

To everyone's surprise except Dr. Abbett, the new fabric out-performs both traditional hydroentangled DuPont fabrics and the polyester-binder fabrics in several areas. The most significant improvements can be found in the area of improved yield, reduced rework, and cost reduction of consumable supplies.

YIELD

One of the first field trials was at a large U.S. subcontractor. The test was run on five SMT lines using Indium 92J solder paste, and a stencil roll with binders. Their normal yield of 97.2% was significantly lower than the yield using the new developmental paper, which jumped to 99.5% on the 392 boards tested. This was a very promising development. As one engineer has commented to the author, "I'd cut off my arm to improve my yield half a percent."

A separate test in the U.S. took a look at the quality of the solder joints. Using 2-D and 3-D inspection systems, the engineer tracked an 8% increase in the average height of solder paste deposited on each inspected pad. The result was a statistically significant increase in yield due to fewer solder paste problems (solder balls, voids, insufficient solder paste and solder bridges, etc.) and a concomitant reduction in rework.

One of the most intriguing test results came from a facility in Mexico. It has long been suggested that solvents have a deleterious effect of the rheology of solder paste. When the engineer found the developmental paper out-cleaned the current stencil roll he reprogrammed the printer to clean without using any solvent (that is, wiping dry). The result was a reduction in defects from a rate of 8,104 parts-per-million to zero parts-per-million. The combined test run was 4,000 boards. Further research is planned to see if this result can be duplicated in other facilities.

The most clear-cut measurements of improvement came from a large subcontractor in northern Europe. Using Alpha Metals paste on MPM printers with electroform stencils, they were having trouble sustaining their yields. Part of their problem was their current stencil roll, a polyester-and-glue product from Europe, that only provided a capability index (“CPk”) of 0.88 [Note 4]. Since the company’s standard was a CPk 1.30, the engineers knew they had a problem. But, due to the industry’s blind spot, they were unable to resolve it until samples of the developmental paper were made available.

The new paper made a significant improvement. It delivered a CPk of 1.70, substantially better than even a five-sigma quality level. The standard deviation of the old paper was twice the size of the new paper. This means the new paper enabled a printing process that was tighter around the mean, so fewer boards will be produced outside of the printing parameters. Using a few rough estimates about the size and density of the boards, this printing performance suggests that the old paper would produce 800 bad solder joints every 2000 boards while the new paper would have none. In short, changing the stencil roll added more than 2 sigma to the quality of their production.

REWORK AND CONSUMABLES

Everyone in the industry acknowledges the expense of rework. If an enterprise could focus on Philip Crosby’s “do it right the first time” quality program [Note 5] the savings would fall right to the bottom line.

Rework was the focus of a prolonged test in Hungary. The new developmental paper was pitted against the classic Sontara® paper. The first pass yield jumped to 99% from only 95% with the old paper. This led to a 77% drop in rework. The rework savings were estimated to be 168,000 euros annually.

Another company in Hungary found an unexpected savings from the new developmental paper. This company was able to reduce their cleaning cycles per shift from 50 to 25 on both their DEK and MPM printers. This doubled the life of the stencil roll resulting in an overall reduction in roll costs of 12.4%. Since large facilities can have six-figure budgets for stencil rolls these savings can be substantial. Related savings were found in misprints and solder paste waste.

CONCLUSIONS

Dr. Abbett's research has challenged the conventional wisdom of the industry. It seems there are statistically significant differences in the performance of different stencil wiping papers. In addition, one particular stencil wiping fabric offered superior performance in laboratory tests. Out in the field, the new material made statistically significant improvements in yields, rework and the cost of consumables. The data would suggest that the cheapest stencil wipe to buy may very well be the most expensive stencil wipe to use.

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[3] Bob Ries, “3-D Post-Printing Inspection”, *Circuits Assembly Magazine*, June 1998. Note: Interestingly, Mr. Ries attributes 60% of the total production defects to solder paste/printing defects.

[4] “Capability Indices” are beyond the scope of this article, but generally measure the production performance of a system in relation to a specified standard deviation and mean. Higher scores are better. A CPk of 2.0 equals six-sigma quality. For more details, the author recommends the highly readable web site, http://www.qualityadvisor.com -- Search for “CPK” references. A particularly illuminating page is found at: http://www.qualityadvisor.com/library/six_sigma/six_sigma_inside_story.htm

[5] Crosby, Philip; "Quality Is Free", Penguin-Putnam Books, New York, 1980

Related Information:

- For additional information about the ozone-safe DuPont HFC solvents, check out the Vertrel® solvents web site.
- For other information about the Bromothane™ brand of nPB solvents, check out the Bromothane™ web site.
- For additional help, use the *Solvent Selection Guide* in this Site to help determine the optimal recommendation.
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