Optimization of Robotic Soldering Process: A Focus on Solder Spread and Spattering

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INTRODUCTION

Robotic soldering is a growing market within the PCB Assembly industry and interest in robotic soldering equipment and applications is increasing every year. This method is more efficient than hand soldering and will aid in alleviating human mistakes. The robotic soldering process is more controlled and repeatable than a selective soldering fountain, and it can increase productivity and profitability. As the industry grows, we've found that there is not enough published data regarding this soldering technique. In this paper, we will present how cored wires with different flux percentages will affect robotic soldering performance. All wires used in this project were SAC305 alloy with a 0.020" diameter and 3%, 3.5%, 4%, or 4.5% of flux.

Reasons for Adoption

It is the evolution of the manufacturing and production processes that have led electronics assemblers and assemblers in other industries to wide use of robotic soldering. In the overall evolution of manufacturing, what started as physical work moved to mechanical work, and later progressed to assembly line work. Gradually, the evolution towards computer assisted work continued until it reached where we currently stand with the availability of programmable, fully-automated work. Robotic soldering machines, as we know them, appeared in the early 1980's and have advanced since then into the efficient and reliable equipment that is commonly found today.

There are multiple reasons for adopting an automated soldering system into the PCB assembly process. First, and possibly most importantly, is the consistently accurate and repeatable application of solder to the desired joint. The robot, once programed, will apply the same amount of solder and heat to the desired solder joint location for the same amount of time, every time. Increased repeatability allows for reductions in manufacturing costs in areas such as personnel and the amount of rework needed.

Regarding personnel, it has been observed that more skilled hand soldering experts are exiting the employment age and the next generation of operators is lacking in the skills required to meet the IPC's standards. This deficiency in new skilled operators brings assemblers to a crossroads: one direction leads to training new operators and anticipating that they remain with the company long enough to see a return on the investment, or investing in an automated soldering system and relying on the equipment manufacturing and engineering teams to install a highly-reliable soldering process.

Benefits

Efficiency and versatility are among the advantages of including an automated soldering machine within the assembly process. Due to the increased consistency and reliability, there will be less need for reworking a board, saving users both time and labor costs. Once fully optimized, the equipment purchaser will be able to see a measurable return on investment through improved throughput.

Applications

An assembler would consider using robotic soldering where impossible or unreliable to use mass soldering (wave soldering or solder paste) and where human soldering is too unreliable or too expensive. There may be instances where defects happen frequently with mass reflow techniques or with human hand soldering that need to be eliminated. It could also be that the component being assembled is heat sensitive and requires that only the joint area be exposed to heat and not the entire component. Another possible application would be a large component addition that would make the mass reflow profile too difficult or too slow.

An application where robotic soldering would not be ideal are those where it is too costly or time consuming to solder each joint individually. For instance, mass soldering techniques, such as wave soldering, would have the ability to bond many joints more quickly. Another situation where robotic soldering may not be the best assembly technique would be where a human decision is required; human operators have the ability to adjust more quickly if needed.

Applications where robotic soldering can be found include:

i. Circuit boards
ii. Wires
iii. Flex circuits

In industries such as:

i. Automotive
ii. Aerospace
iii. Medical
iv. Consumer electronics

FLUX-CORED SOLDER WIRE'S ROLE

What makes a good cored wire, according to a robotic soldering *equipment supplier*?
During the course of our experiment, there was extensive discussion regarding the features that would allow robotic soldering to work most efficiently. To summarize that discussion, we'll note the main three attributes desired by robotic soldering equipment manufacturers and their customer.

First, it is important that the solder **feeds well** into the machine and to the solder joint. From a solder supplier's perspective, this means that the solder wire should be evenly wound in order to prevent kinks in the machine. It is important that there is enough tension placed on the wire as it leaves the spool and enters the machine's feeding mechanism; this helps prevent kinking or too much slack in the wire, both of which can cause the wire to break if pulled with enough force. Feeding well also means that the wire should be void-free, meaning that there will not be any gaps of wire which contain an empty core. Voids in the wire will likely result in poor wetting and subsequent downtime once realized.

The next noted characteristic is that the solder **flows well**. Solder that flows well will pre-tin the iron fully and then, once applied at the joint, will flow effortlessly to create the desired joint. Achieving effortless flow will require the fine tuning of factors such as wire diameter, flux formula, flux percentage, tip temperature, and dwell time.

The last characteristic to mention regarding the solder wire is that the solder wire **does not damage the soldering iron tips**. The soldering iron is one of the most important pieces of the robotic soldering machine and of the robotic soldering process; it is not an aspect that can be overlooked. The soldering iron must be able to repeatedly provide a consistent supply of heat to the solder joint and the type of formula used or the ingredients in a core flux formula can have dramatic effects on the speed of degradation of a soldering iron. Regarding the soldering iron's tip, it is vital that the correct type and size of tip be used based on the application to fully optimize the soldering process.

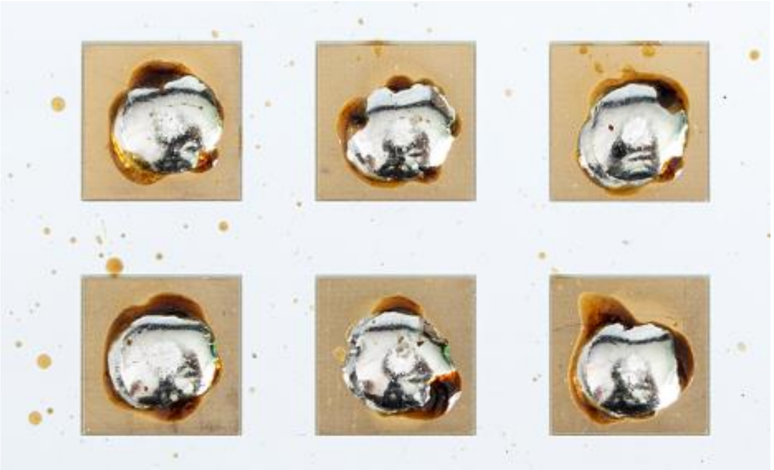
According to a robotic soldering equipment *user*, what makes a good cored wire?
Once installed, the soldering wire that is used will likely be determined either by the in-house engineering team or by a recommendation from the equipment supplier. In either instance, the solder wire characteristics listed in the equipment supplier section would apply for the customer as well. Solder that feeds well and flows well would be desired attributes for the assembler. A wire that feeds and flows well allows for consistency and accuracy in the process, while also possibly producing the desired effect of improving the overall cycle time of completing the board by reducing the need for extra rework. Soldering iron tip degradation would need to be taken into consideration when determining what flux formula to use. Excessive need for re-installation of soldering iron tips reduces the overall cycle time as well as increases the overall cost of assembly.

An attribute not mentioned previously concerns the cosmetics of the board post-soldering. It is known that some flux formulas are prone to spatter more than others. This has become such an important characteristic for this part of the electronics assembly industry that solder wire suppliers are now releasing formulas with 'low-spatter' packages included to improve post-soldering cleanliness and aesthetics.

SPATTER MATTERS

What is Spatter? Spatter refers to the explosive spray of materials (flux and possibly solder) that spit out from the wire after heat has been applied. It is often caused by the outgassing of the flux during the soldering process.

POOR SPATTERING PERFORMANCE (3%)



EXCELLENT SPATTER PERFORMANCE (3%)

Critical Side Effects to Be Avoided

During automated and manual soldering, spatter is not only cosmetically unappealing, but it also increases cleanup time, wasted material, and could, in theory, impact the processing performance of sensitive components. It can also cause an exposure burn to the manual soldering operator.

Spattering in robotic soldering applications can also have an undesired effect on the soldering machine's visual inspection system. A visual inspection lens covered with spattered flux will not be able to detect the defects that it is programmed for as effectively as a clean visual inspection lens. This can later lead to issues on the production line, such as more rework needed, having to dispose of the boards, and even affect the finished good's life cycle if the issues are not caught prior to shipment.

Measuring Spatter and Our Test

Test parameters

- i. Tip
  - a. Size: 3mm
  - b. Temperature: 400°C (752°F)
    - i. Note: 425°C saw more spatter w/ 4.5% flux core
- ii. Board: Aluminum-clad, preheated @ 160°C (325°F)
- iii. Wire
  - a. Diameter: 0.020" (0.50mm)
  - b. Formula type: No-clean

c. Flux percentages: 3%, 3.5%, 4%, 4.5%

What are we testing?

i. Flux percentage effect on spattering
ii. Flux formula effect on spattering

MAIN CONCLUSIONS

Spattering is influenced by formula more than flux percentage

In a robotic soldering assembly process, there will not be any direct human interaction in regard to forming the solder joint. Therefore, it is generally accepted that the assembler will want to use as much flux as possible to ensure wetting occurs and the ensuing solder joint is adequate. When the flux percentage was increased from 3% incrementally to 4.5% using the same core flux formula, there were some improvements shown in the rate of wetting and the spread of the solder. While this may be attractive when considering cycle times and overall production output, there is another factor that should be considered: spatter. In our study, it was determined that **spattering is influenced by formula more than flux percentage.** As can be seen in our formula control group, the spattering performance of each board is relatively similar using flux percentages ranging from 3% to 4.5%.

Control Group

3.0%

3.5%

4.0%

4.5%

Other Conclusions

ROL0 < ROL1 < ROM1

The results showed that not all flux percentages and activity levels were created equal. As was expected, the activity level of the flux at 3% of the core improved congruently with the appearance of spread and wettability, meaning that testing done with a J-STD-004A ROL0 did not performance as well as a J-STD-004A ROL1, and both performed inferior to a J-STD-004A ROM1. However, in regards to spattering, it should be noted that as the activity level went from 'L' to 'M', there was a tendency for decreased spattering performance, as can be seen below.

ROL 3.0%

ROM @ 3% - A

ROM @ 3% - B