As originally published in the SMTA International Conference Proceedings.

PROCESS CONTROL
BASIS FOR A COST-EFFECTIVE SELECTIVE SOLDERING PROCESS

Christian Ott
SEHO Systems GmbH
Kreuzwertheim, Germany
christian.ott@seho.de

Heike Schlessmann
SEHO Systems GmbH
heike.schlessmann@seho.de

Reiner Zoch
SEHO Systems GmbH
reiner.zoch@seho.de

ABSTRACT
Compared to other soldering processes, the selective soldering process is considered as particularly demanding.

Structures with small pitches or small distances to neighboring components result in a small process window and provide less room for potential failures.

From conventional wave soldering we already know that variable parameters, such as the flux quantity, preheat time and temperature or wetting time and solder temperature can play a decisive role for a "high quality" or "low quality" solder joint. These variable parameters are to be considered even more critical in selective soldering processes.

Therefore, precision and accuracy of the equipment are a MUST to avoid costly rework.

A controlled and reliable selective soldering process is a basic requirement for approaching a zero-fault-production. Even potential operator faults should be detected and – if possible – have to be eliminated by the machine.

Modern control units and easy to handle software provide the basis for a complete process control and thus build the cornerstone for a cost-effective selective soldering process. Control functions for the different process steps, as fluxing, preheat and soldering, as well as additional features such as fiducial recognition or process visualization on the one hand are decisive, on the other hand they are helpful tools to ensure a reliable selective soldering process.

This paper will give a comprehensive survey about the single process steps and which possibilities exist to monitor and control them.

Key words: Selective soldering, process control, cost effectiveness.

INTRODUCTION
Particularly in lead-free soldering processes but also when using conventional SnPb solder alloys, process-related faults may occur.

One of the most frequently experienced solder faults is the formation of solder bridges between two or more pins of a component. As for many typical solder faults, several facts might be the reason for this. Particularly in lead-free applications the reduced weight-force of the alloy causes a declined flow-off of the solder which finally results in solder bridging.
Bridging, however, also might be caused by an inadequate quantity of flux applied to the solder joints or insufficient preheating of the assemblies.

Insufficient through-hole penetration is another typical process-related soldering fault and besides the option that the connecting partners, e.g. the printed circuit board and / or the component, show a bad solderability, also in this case either an insufficient flux quantity or preheat process might be the reason for this phenomenon. Moreover, the soldering temperature or soldering time can cause an insufficient hole penetration.

Another typical solder fault which can occur both in wave and selective soldering processes is the formation of cones (Figure 1). Most frequently, cones are caused by an insufficient preheat process or inadequate energy transfer during the soldering process. But also an insufficient flux application might be the reason for cone formation.

Figure 1. Typical Solder Fault – Cone Formation

These are only some of the possible soldering faults. All of them are related to incorrect parameters for fluxing, preheating and soldering. This verifies the basic necessitiy to monitor and control these process steps in order to achieve the required soldering quality and to avoid costly rework.

Particularly in selective soldering processes one has to consider that insufficient flux or heat energy supply might not only be caused by incorrect quantities of flux or temperature settings. It also has to be taken into account that the printed circuit board itself could be positioned incorrectly so that flux and solder wave are not precisely applied. Thus, the exact positioning of the assemblies should be controlled as well.

PRECISE BOARD POSITION

Already common for the printing and placement process, but so far not for the soldering process, is the control of the correct position of the printed circuit board during the process.

A fiducial recognition system for selective miniwave soldering processes allows to optically register the printed circuit board to be soldered and compensate for various types of misalignment such as offset, rotational error and linear shrinkage within the PCB. As a side effect wrongly placed assemblies are detected and will not be soldered. Algorithms for pattern recognition base on grey scale images. Recognition accuracy is 1/5th of a pixel or better. This means that with typical camera resolution and comfortable size of view the recognition accuracy is in the range of 0.01 mm or better (Figure 2).

Globally for the complete manufacturing panel or alternatively for each sub panel separately, two or three fiducial marks are selected by the operator in a learning procedure. The user selects any arbitrary type of fiducial shape, adjusts the rotation and size of the shape and finally indicates the exact position of this fiducial on the printed circuit board. The software captures exact images of these fiducials and memorizes their exact location. After having "learned" all fiducials, the machine will in all subsequent runs automatically move to the previously memorized positions and capture an image of the board at that point. The correlation between this actual "live" image and the "learned" – ideally positioned – image is calculated and gives a resulting offset vector for this position. The same is done for all fiducials and finally error vectors for all fiducial positions are obtained and fed into a mathematical model that allows to calculate offset, rotation and linear shrinkage of the actual printed circuit board compared to the "golden" board that was used for the learn run.

The result is a correction matrix used for compensation and position correction for any single production run.

In addition, the fiducial recognition software tool contains an error proof function which checks the loading of the correct soldering program and controls each board for precise positioning. Therefore, even possible operator faults can be recognized and compensated.

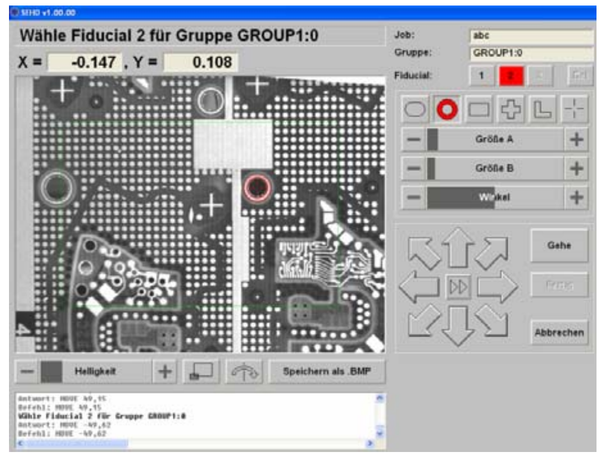

Figure 2. Fiducial Recognition for Selective Soldering Processes

CONTROL OF THE FLUXING PROCESS

Particularly in selective soldering, the precision of the process plays a decisive role. This primarily applies for the flux application. During the last few years, micro drop jet fluxing has turned out to be the most suitable method. Drop jet fluxers guarantee exact flux application to the point with a precisely defined quantity, thus ensuring that surrounding areas which are not meant to be soldered, will not be wetted.

On the other hand it has to be assured that enough flux gets to the solder joint so that a sufficient hole fill is achieved to form high quality solder joints during the subsequent soldering process.

Flux control systems are, therefore, essential. There are different ways to control the flux application. The easiest but not most reliable way is to control the function of the drop jet nozzle. This usually is performed in a test cycle prior to the actual flux application to the printed circuit board. During this test cycle a specific sensor is wetted with flux. This sensor shows whether the function of the nozzle is alright at the time of the test (Figure 3). It is, however, not possible to make a statement about the function of the drop jet nozzle during the actual production process and moreover the flux quantity being applied to the printed circuit board cannot be clearly defined.

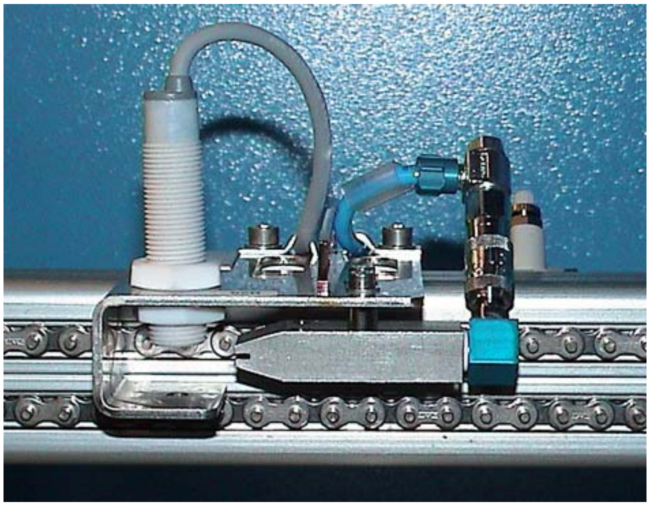

Figure 3. Monitoring System for the Drop Jet Nozzle

Much more reliable is a real quantity drop jet fluxer control. This control system does not only monitor the function of the drop jet nozzle. It in fact measures the actual flux quantity jetted by the drop jet nozzle during the fluxing process (Figure 4). The measured quantity is compared to a reference value learned earlier. In case the system detects a deviation, an error message will be initiated. In addition, the software clearly indicates, which part of the printed circuit board has not been fluxed correctly.

This type of fluxer control ensures highest process reliability and constant process conditions without any influence on the cycle time.

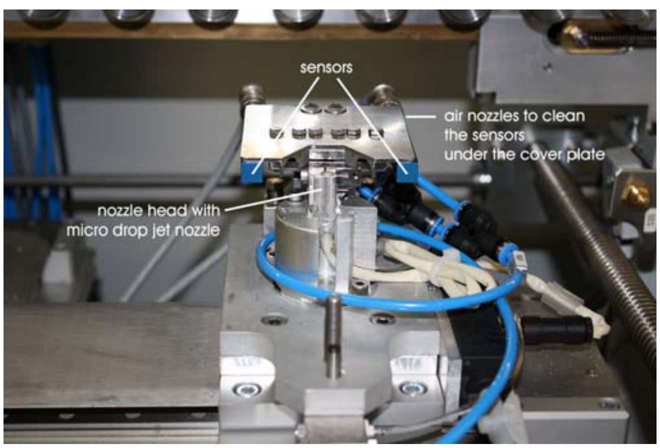

Figure 4. Real Quantity Flux Control System

CONTROL OF THE PREHEATING PROCESS

Monitoring of the preheat temperature is essential to ensure reproducible temperature profiles.

One of the most common and also one of the most reliable methods to monitor and control the preheat temperature is the use of infrared thermometry.

Depending on the temperature each object emits a certain amount of infrared radiation. A change in the temperature of the object is accompanied by a change in the intensity of the radiation. For the measurement of "thermal radiation" infrared thermometry uses a wave-length ranging between 1 µm and 20 µm. The intensity of the emitted radiation depends on the material. This material contingent constant is described with the help of the emissivity which is a known value for most materials.

Infrared thermometers are optoelectronic sensors. They calculate the surface temperature on the basis of the emitted infrared radiation from an object. The most important feature of infrared thermometers is that they enable the user to measure objects contactless. Consequently, this helps to measure the temperature of inaccessible or moving objects without difficulties.

Infrared thermometers basically consist of lens, spectral filter, detector and electronics. The specifications of the lens decisively determine the optical path of the infrared thermometer, which is characterized by the ratio distance to spot size.
The spectral filter selects the wavelength range, which is relevant for the temperature measurement. The detector in cooperation with the processing electronics transforms the emitted infrared radiation into electrical signals. [1]

CONTROL OF THE SOLDERING AREA

The soldering area – as the heart of the process – should be paid special attention to, as many variables can influence the soldering results. The focus here, for example, should be laid to the temperature of the solder alloy, the solder level or the wave height.

The easiest way to monitor the soldering process is a permanent visual control. A high resolution CCD camera is installed within the process area focussing on the soldering process. The corresponding live picture is displayed on a separate monitor. This enables the user to act immediately in case the soldering process should not be performed as intended. It is, however, not possible to record the live pictures for later analysis.

A constant and stable solder wave height is decisive for a reproducible soldering quality. The wave height depends on the pressure in the pump channel of the solder bath. This pressure consists of two components, the basic pressure which depends on the solder level in the solder bath and the pressure which results from the pump speed.

Total Pressure = Solder Level Pressure + Pump Pressure.

Therefore, it is the task of a control system to keep the total pressure (wave height) stable. The coarse adjustment is carried out via the stabilization of the basic pressure (solder supply). The fine adjustment is carried out via the adjustment of the pump pressure (pump speed).

A very uncomplicated way to control the level of the solder alloy in the solder bath is the use of a floater which is mounted at a rocking bar and permanently monitors the solder level. As soon as the solder level falls below a certain preset value, a signal is given to the control unit which either initiates an error message to indicate that solder has to be refilled manually, or it activates an automatic solder supply.

Another way of controlling the solder level is a measuring needle which is brought into its control position by the handling system. If the measuring needle dives into the solder, an electrically leading connection is made, i.e. the solder level is correct. If no contact is made, the solder supply starts automatically.

The solder level control also can be performed by means of a nitrogen differential pressure measurement.
Nitrogen is led through a differential pressure load cell to the solder pot where it escapes through a nozzle. If the solder alloy rises and blocks the nozzle, the pressure in the supply line increases. If the solder alloy falls, the nitrogen nozzle is opened and the pressure in the supply line decreases. By means of the pressure differences, the solder level in the solder pot is monitored.

There are several ways to control the pump pressure and thus the solder wave height which is another critical parameter during the process.
The wave height control is necessary to ensure constant and reproducible process conditions.

The easiest way is a measuring needle made of titanium or any other resistant material, which is located somewhere in the process area (Figure 5). Based on a particular cycle the solder bath automatically is moved to the measuring position. For systems with a stationary solder pot, the measuring needle can be installed at the handling system, such as a gripper for example. With its pinpoint the measuring needle performs a contact measurement at the surface of the solder wave. This causes an electrical signal and the pump speed is regulated to the necessary speed to achieve the preset wave height.

Figure 5. Measuring Needle to Control the Solder Wave Height

As the measuring needle only carries out a contact measurement and does not dip into the solder it is important that the atmosphere is kept stable. Changes in the surface tension lead to a different measurement result. One disadvantage of this method is that the production run needs to be interrupted to control the solder wave height. The cycle time, therefore, is negatively influenced.

Independent from the cycle time is a solder wave height measurement by means of Eddy Current sensor which simultaneously also controls the solder level in the solder bath. A measuring funnel, which has the same level as the solder nozzles, is connected with the pump channel. Based on the principle of communicating tubes, which is an indirect measurement, an identical solder wave height arises at the measuring funnel (Figure 6). As soon as the solder wave height falls below a certain value, a signal is initiated and sent to the control unit. Depending on this signal the pump speed is regulated to the necessary speed to achieve the pre-programmed wave height.

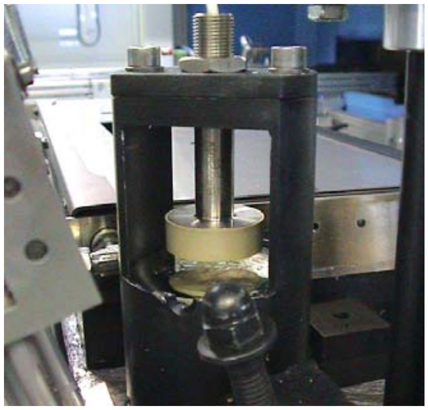

Figure 6. Eddy Current Sensor for Control of the Solder Wave Height

Another independent method for wave height control is a light barrier which contactlessly measures the height of the solder wave shortly before the soldering process is performed. As with the other methods, the solder wave height is regulated by adjusting the pump speed.

Highest reliability offers the wave height control with a laser measuring system (Figure 7).

Such a measuring system delivers several advantages. The measurement procedure is performed simultaneously to the production, i.e. there is no influence on the cycle time. In addition, the change of the pump speed affects the measuring signal very fast. Because of the continuous measurement potential problems in the pump system can be recognized very quickly and this direct measurement of the solder wave height is also able to recognize soiling in the nozzle system which might effect the soldering quality. Moreover, the wide measuring range of the sensor and the adjustment to zero at the top edge of the solder nozzle enables the use of nozzles with different height. The laser measuring system consists of a sensor unit which incorporates a transmitter with receiver and a control unit.

Transmitter and receiver are installed on two sides of the selective soldering system having the same level as the solder nozzle. The system is adjusted to zero at the top edge of the solder nozzle and thus measures the difference between nozzle top edge and solder wave top edge. The wave height is kept on a constant level by adjustment of the pump speed. If the measured wave height is too low, the pump speed is increased. If the measured wave height is too high, the pump speed is reduced. The pressure of the pump system is changed to keep the total pressure on a constant level.

At the same time, the actual pump speed is compared to the speed which has been determined during referencing. If the actual speed is higher than the reference speed this indicates that the solder level has fallen below the nominal value. New solder has to be supplied until the actual speed is reduced to a speed which is less or equal the reference speed.

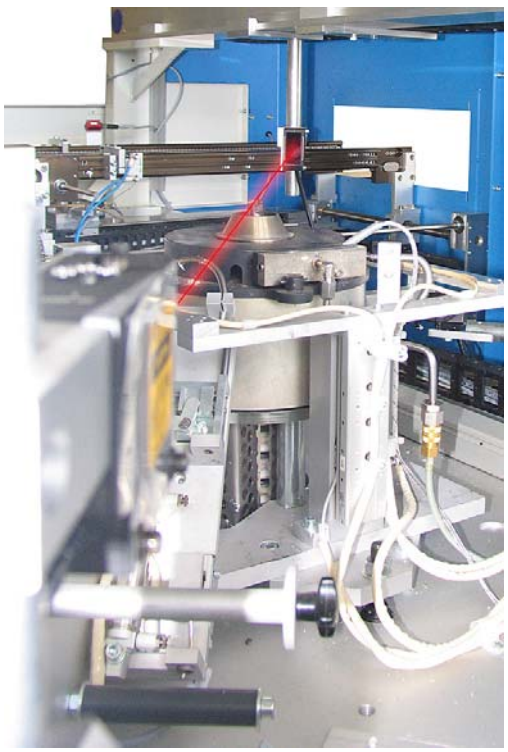

Figure 7. Laser Measuring System for Control of the Solder Wave Height

Additional control functions help to avoid potential failures or to eliminate operator faults.

Such control functions, for example, are intelligent tool management systems for machines being equipped with two soldering units and / or for electronic manufacturing companies running a mixed production of different assemblies.In case of the automatic assembly-tool-verification the machine recognizes the incoming printed circuit boards. This control function allocates each board to the soldering unit which is equipped with the corresponding solder nozzle tool.

The automatic tool-solder program-verification uses a particular coding system for the different product-specific solder nozzle tools. Each tool then is allocated to its corresponding soldering program.

Finally, the automatic gripper-solder program-verification also uses a special coding system. As a result, the gripper is allocated to the corresponding soldering progam.

In either case, the control unit initiates an error message if any deviation from the preset reference should be detected to avoid damaging of the assemblies to be processed or of the machine.

CONCLUSIONS

The target of a zero-fault production is the main driving factor for the control of the selective soldering process. Only if all process steps are performed absolutely reliable and repeatable, costly rework can be avoided.

Control functions which are part of a selective soldering system are independent from the human circadian rhythem. Particularly for users producing electronic parts for the automotive industry, these control functions will help a lot to proof the stability of their processes and thus ensure a soldering quality at highest level.

REFERENCES

[1] Optris GmbH, Berlin, Germany, Instruction Manual for Optris CT, pp. 50.