A Test Procedure for Measuring Print Quality

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ABSTRACT

This procedure describes a measurement method, which introduces critical variables defining print quality. The first, matrix levelling, takes account of non-flat surfaces or related samples. The second is the calculation of PVO (pseudo-virtual object) parameters, deposited volume, PVO angle (related to slumping and bridging) and mean height. Major attributes of the proposed data analysis algorithm are insensitivity to the location of the printed deposit and the location of any specific defect. This algorithm coupled with variables defined in the analysis package delivers a new and flexible approach to measuring the quality of printed media.

1. Introduction

In Figure 1 a solder paste deposit printed on a copper substrate is shown, illustrating the typical wall slope after solder paste release from the stencil. This wall would ideally be perpendicular to the base plane, and a copy of the stencil aperture edge. As the solder paste comprises alloy particles suspended in a gel, the cohesive forces help to retain the deposit shape and only minimal slump occurs before component placement. Slump is also partly restricted by the definition of the copper PCB pads.

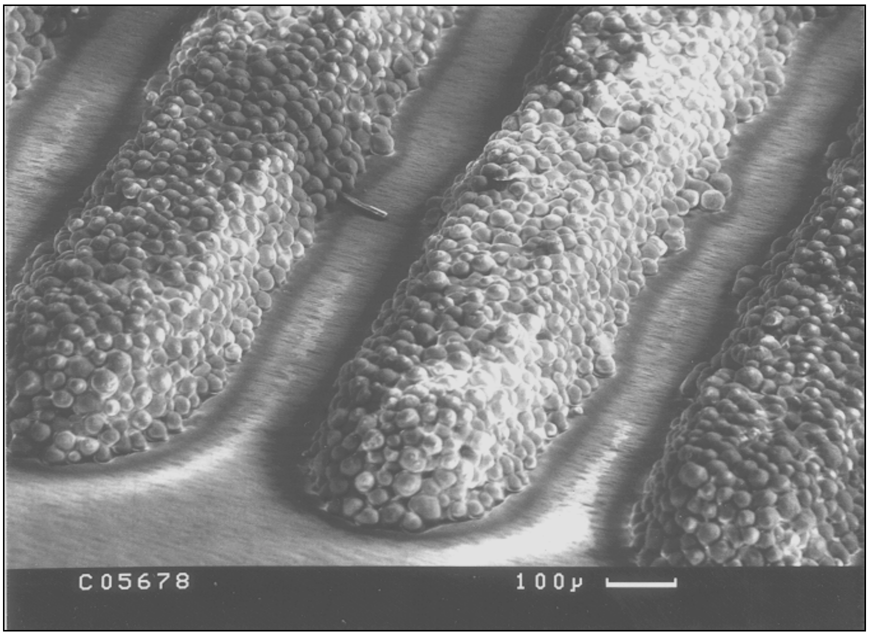

Figure 1: Solder paste deposits stencil-printed on Cu substrate

2. Measurement Technique

A typical acquisition technique is based on the triangulation technique with a CCD sensor, this provides data of an acceptable accuracy and time for industrial applications [3]. A schematic of such a system is shown in Figure 2. The measured height points are stored in a two-dimensional matrix and can be processed with built-in algorithms to give characteristic feature dimensions. The accuracy of the measurement for solder paste deposits is typically around ±10 µm, which is comparable to the solder particle size, i.e. minimal object size (solder balls with diameter of 25-40 µm). An example of scanned matrix contour plot of a printed deposit (representative of QFP pads) is presented in Figure 3.

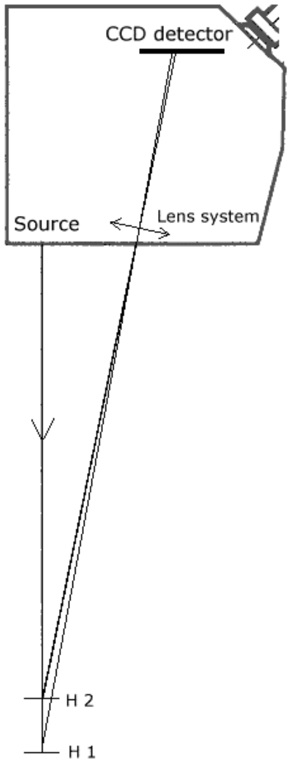

Figure 2: Schematic of laser triangulation sensor

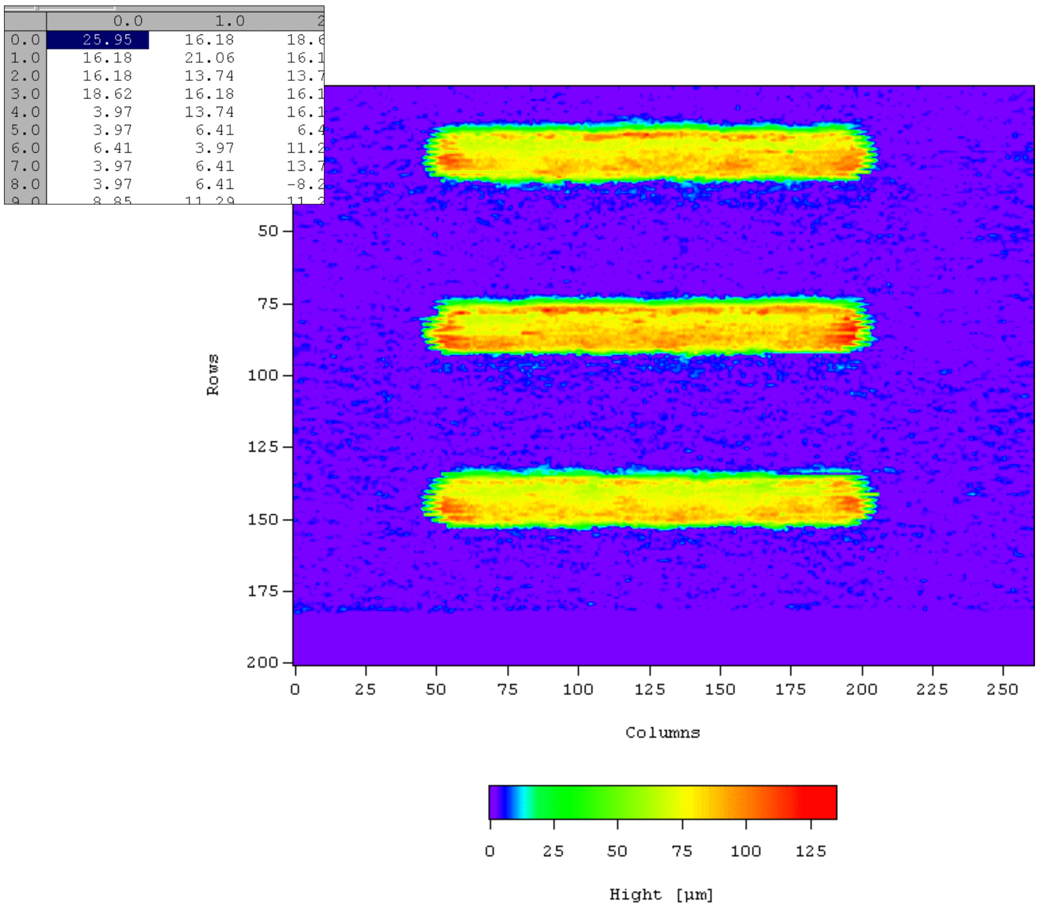

Figure 3: Example of contour plot of a scanned matrix

2.1. Requirements for robust output parameters

The main requirement for making credible measurements is to reduce the impact of specific features, and allow robust measurements of volume and height that are not sensitive to localised anomalies in the print deposit. Point or line scan measurements are prone to such errors. The method should also be capable of account of features such as bridging and skips. Many systems are capable of measuring volume, but detection and measurement of slump and bridging is more problematic. A significant issue is the location of the defect. Location of the defect is further compounded as print quality deteriorates, as general edge definition of the print deposits is lost. Any method should be intrinsically flexible and produce meaningful measurement parameters for a range of patterns; e.g. QFP, flip-chip, discrete chip components. For the key aspects height, volume and shape the analysis method should produce output parameters that are equivalent between different component patterns and are easy to assimilate and provide a suitable basis for comparison. In any analysis of bridges and slump knowledge of the print array is necessary, as this influences the ratio of the perimeter to area for the printed deposits. Any algorithm must therefore take print shape and deposit array into account. The measured values should be on a continuous scale, so that pass/fail criteria can be set. An issue with some measurements is the alignment of the print with the measurement axis. Identification of a bridge in a simple geometric approach requires the analysis to look in the right place, hence the required alignment. A method that doesn't require the board or the print data within the matrix to be rotated to achieve alignment will clearly be advantageous. Finally, as with any kind of measurement a high signal/noise ratio is essential.

3. Algorithm Description

The method introduced here for processing height data from a scanned sample compromises two main steps:

1. Matrix levelling (triangulation levelling of the base plane)
2. Calculation of Pseudo-Virtual Object (PVO) parameters (volume, PVO angle, mean height)

The levelling stage is an important step to carry out, but most systems assume a flat substrate, and hence a uniform reference. In this procedure the matrix is levelled as a matter of routine.

3.1. Matrix levelling

The matrix levelling is based on a simple subtraction of a X-Y-wedge from the measured matrix. Three points (A, B and C) define the constructed plane as shown in Figure 4.

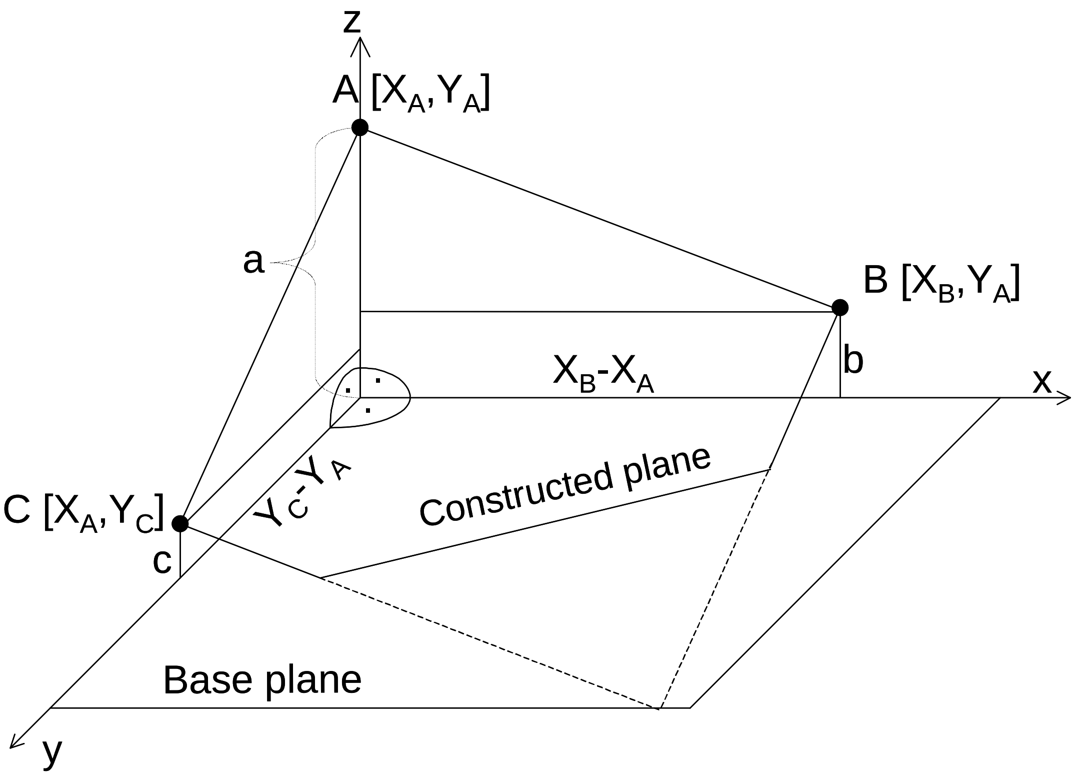

Figure 4 Schematic for matrix levelling

The wedge is calculated from heights a, b and c, and X and Y coordinate differences from the point A. All points A, B and C are used to set the zero height plane, the rest of the matrix is levelled to. Locations of points A, B and C are either chosen by an operator for each data matrix processed or can be preset. The values **a, b, c** are calculated as the median of 5 x 5 sub-matrix, surrounding the nominal positions. This improves the robustness, and removes problems with anomalous single values.

3.2. PVO (Pseudo-Virtual Object) calculation

The calculation of the PVO is based on the analysis of the data matrix and transposing this information into 3D symmetrical shape. A typical starting data matrix is illustrated in Figure 5. The PVO is calculated on specified height ranges (or bins), for a solder paste application the range is typically 10 µm wide starting with 0-10, 10-20, 20-30µm etc. Once the distribution height is known the PVO can be constructed around a cylindrical coordinate system with a base area equal to the scanned area. The PVO is shaped from discs, where the disc height is the mid height of the height range, and the disc's radius is related to the square root of an area falling into the height range. The discs axes are co-located in the centre of the coordinate system and together they build a symmetrical shape (PVO), representing redistributed solder paste deposit.

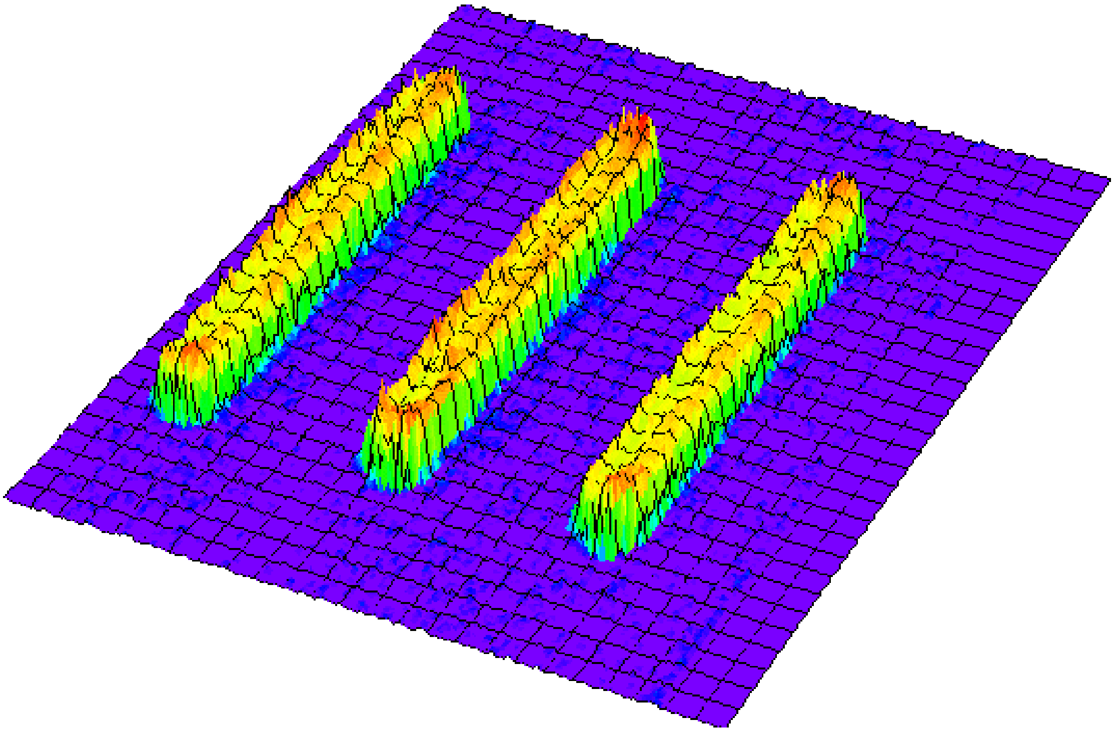

Figure 5: 3D example of a scanned matrix

3.3. PVO parameters

Parameters used for comparing print quality are defined in Figure 6. The main parameter, which can be directly compared to other methods, is **the deposited volume**. This can either be expressed as an absolute volume in mm^3 or ratio or percent of absolute deposited volume and maximum possible deposited volume (stencil aperture volume).

The parameter describing edge definition is called **PVO angle** and it is the tangential angle at the steepest point (inflexion point) of the PVO cross-section profile (blue line in Figure 7). The PVO angle is used in predicting slumping or bridging propensity.

For component lead co-planarity issues there is a need to measure **the mean height** of a print. This is defined as a height with minimal tangential angle (red circle in Figure 6).

Further characterisation of the PVO profile is possible. As seen in the example (Figure 6) a hump around radius = 1500 µm can be associated with propensity to **bridging** because the profile is crossing the ideal aperture radius. The left end of the curve represents a phenomenon called **"dog ears"**, which usually occurs at the end of printed deposits. These peak values can cause wet bridges after component placement.

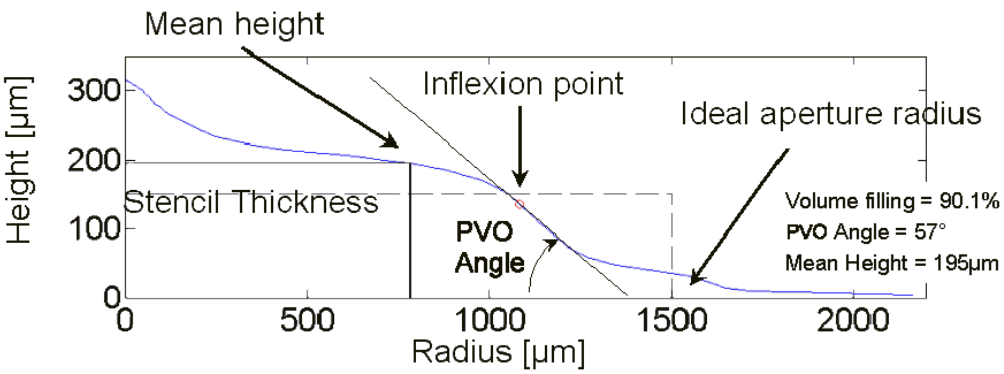

Figure 6: PVO profile and parameters definition

The PVO produced from the data matrix in Figure 5 is shown in Figure 7, the **PVO angle** is 76.1° (at height = 57 µm). The **mean height** of the print is 90µm (at an angle of 5.9°). The top end of the curve represents a phenomenon called **"dog ears"**, which usually occurs at the end of printed deposits. These peak values can cause wet bridges after component placement.

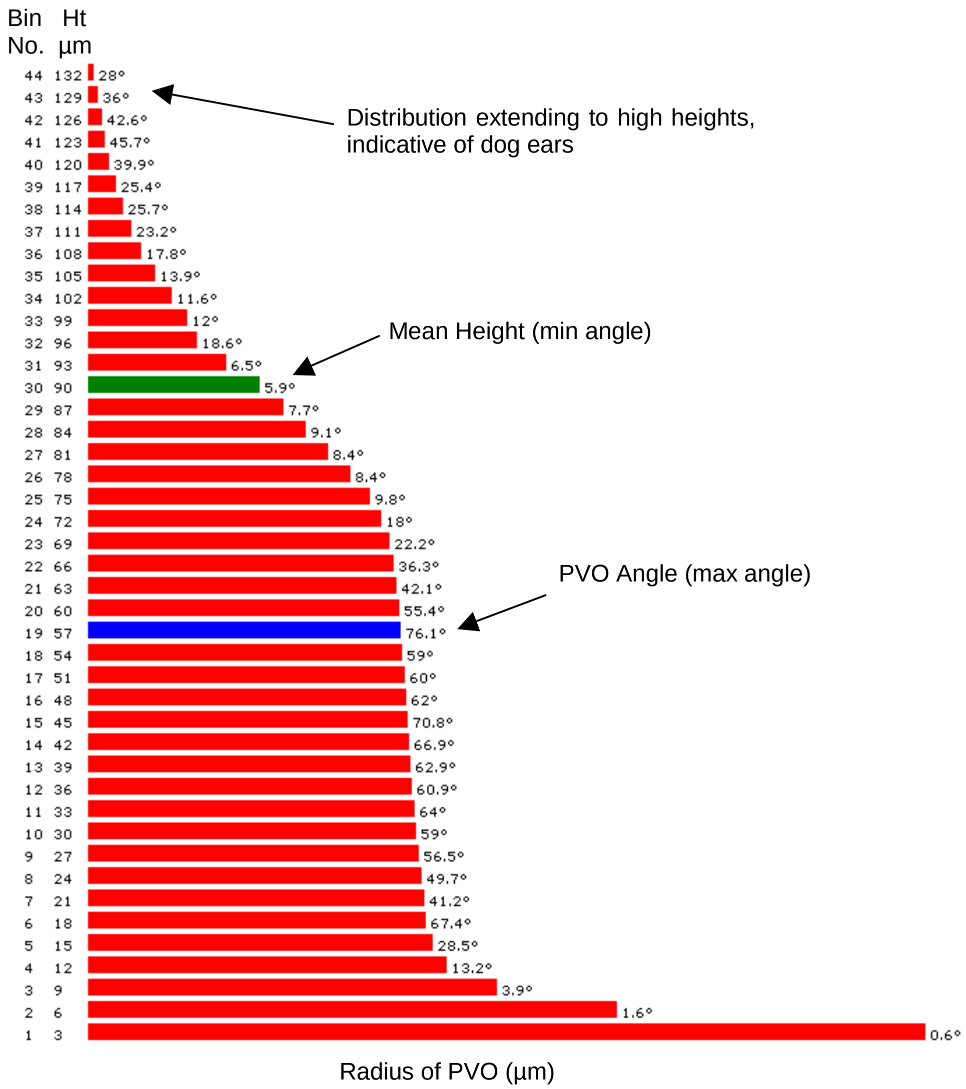

Figure 7: PVO profile derived from Figure 5 indication mean height = 90µm and PVO corrected angle = 76.1° at 57µm

3.4. Correction of PVO angle

Where there are multiple similar features in a scanned matrix i.e. QFP deposits; the PVO angle has to be corrected for the number of features. This allows the PVO angles, from PVOs with different number of features or deposits, to be compared directly. The correction curves are plotted in Figure8, using Equation 1.

$$\alpha = \arctan\left(\tan(\alpha')\cdot\sqrt{N}\right) \qquad \textbf{Equation 1}$$

Where:
α‘ is the calculated PVO angle for a single deposit
α is the corrected PVO angle for N features
N is the number of repeated features

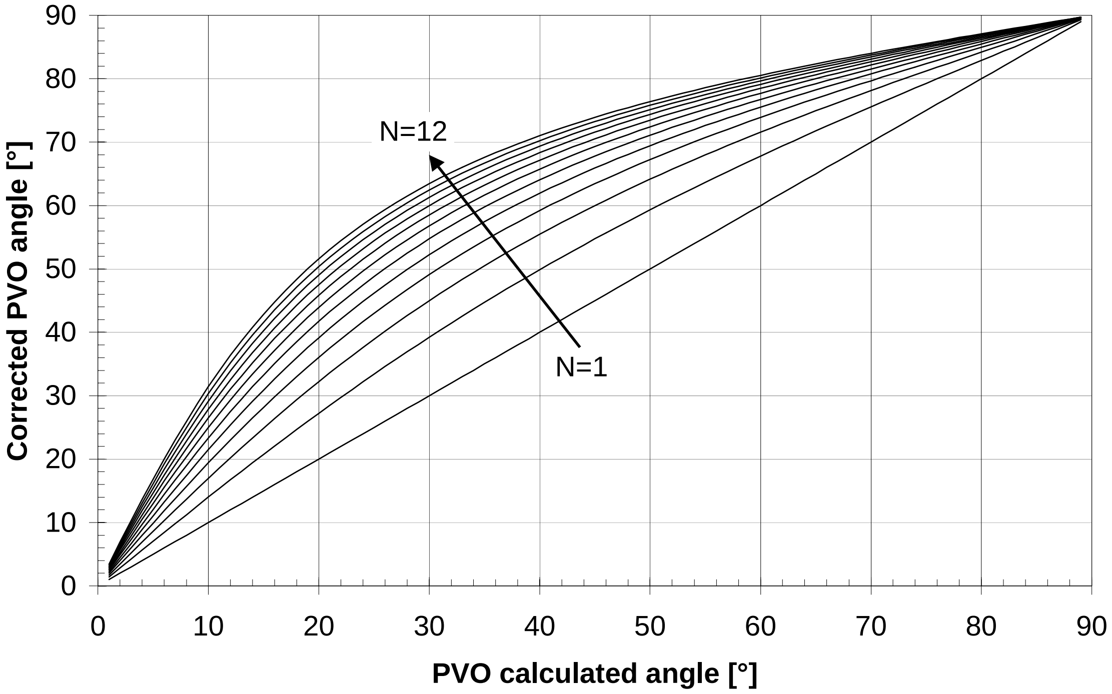

Figure 8: PVO angle correction for multiple deposits (N=1-12)

4. Procedure For Measuring Solder Paste Height

Using the procedures discussed above the following steps should be taken to characterise deposit quality:

- Measure data matrix of deposit heights by any convenient optical scanning technique
- Level the matrix, to remove any instrument distortions from the measurements
- Process the data matrix to form a PVO object. Program available via the web at www.npl.co.uk/ei.

- Extract parameters: volume, mean height, PVO angle
- Correct PVO angle for number of deposits
- Use PVO parameters to characterise deposit quality.

5. Conclusions

Software processing of height scans of printed solder pastes has been used at NPL and is written as WEB based server application (PHP) providing network capabilities.

- In measuring the quality of stencil printing of solder paste, there are significant limitations to those traditional techniques which consider only two metrics, deposited volume and average height

- This technique described here has successfully used a different approach for describing solder paste deposits. It employs two main steps
  - (i) matrix levelling, to take account of non-flat surfaces, rotated samples or even measurement noise.
  - (ii) calculation of PVO (pseudo-virtual object) parameters, deposited volume, PVO angle (related to slumping and bridging) and mean height.

- This technique can be applied to other materials used in electronics production processes (e.g. Surface mount or conductive adhesives, and glob-tops)

- The major advantage of the algorithm used is its robustness and flexibility e.g. in accommodating non-flat surfaces and rotated samples.

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