Measurement of the deformation of PCB and SMD during surface mounting

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***Abstract*—Based on the standard for testing in surface mounting, an area of critical deformation during the assembly of elements has been determined. A methodology for testing and determining the deformation has been chosen, as well as tools for conducting experimental measurements. The results of practical measurements of deformations after soldering are presented. A conclusion is made on the basis of the obtained results with conclusions regarding the admissibility of the process according to the standard.**

***Keywords*— surface mounting, soldering, testing, deformation**

I. Introduction

One of the essential moments in the surface mounting is the optimal design of the board from the position of long-term stability during operation. Some of the reasons leading to board failure are related to the occurrence of assembly defects or subsequent assembly failure [1]. A significant contribution to the appearance of defects, the result of assembly processes, is the appearance of mechanical stress, both in the process of assembly and after it, leading to mechanical defects of elements [2]. Part of the deformation is the result of the different coefficients of linear expansion during heating and cooling and the temperature difference between the hardening point of the solder and the normal operating temperature. To reduce this deformation, the corresponding coefficients of linear expansion and thermal masses during soldering are taken into account [3] or solders with appropriate parameters are used [4].

In all cases, however, the question is to determine the deformations in the specific case and the application of the relevant tests. For this purpose, the standards [5], [6] and a specific measurement scheme are applicable. Depending on the setting [7], a strain gauge type, measurement scheme and impact [8] are selected. If the results are critical, options for additional mechanical hardening by construction and grouting materials [9], [10] or non-standard methods of contact [11] and soldering are sought [12], [13].

II. Experiments

A. *APPLICATION OF STANDARD PROCEDURES*

The purpose of this development is validation and maintenance of technological processes in the production of electronic modules for the automotive industry, by measuring and analyzing mechanical stress.

Multilayer ceramic capacitors (MLCCs), BGA and all SMT components are one of the most widely used in the manufacture of electronic modules. Introduced for the first time in 1977, thanks to their high reliability and extremely long life / decades /, they quickly entered the electronics industry. In order to achieve these high levels of reliability, critical defects due to improper manufacturing and assembly of electronic modules must not be allowed. The causes of defects in MLCCs, BGA, SMT are:

- improper storage and handling – fig.1.;
- temperature shock – fig. 2.;
- excessive bending – fig 3.;
- applied strains.

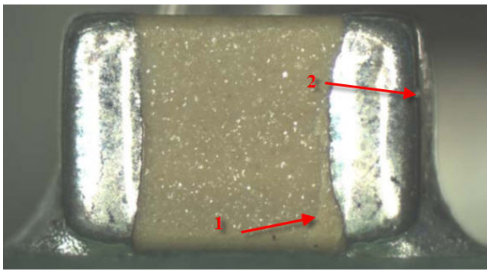

Fig. 1. Damaged capacitor during handling: 1 - in the body area, 2 - in the solder area

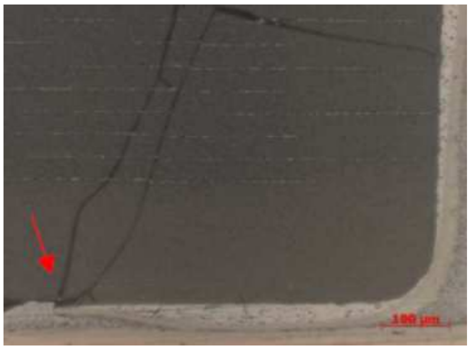

Fig. 2. Damaged capacitor due to thermoshock

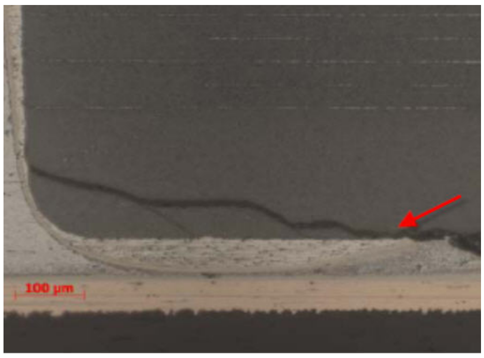

Fig. 3. Damaged capacitor due to bending

The present work is dedicated to the prevention of these consequences and the creation of prevention tools. The paper uses the IPC / JEDEC-9704 standard, which describes the specific guidelines for stress testing of assembled printed circuit boards. The test itself allows to make an objective analysis of the stress levels on SMT components during the assembly process.

B. TEST SOLUTION

In the specific solution a KEMET-MLCC Fex Failure Rate diagram for the allowable stress levels at 1 ppm, 10 ppm, 100 ppm depending on the dimensions of the SMT components is used, shown in fig. 4.

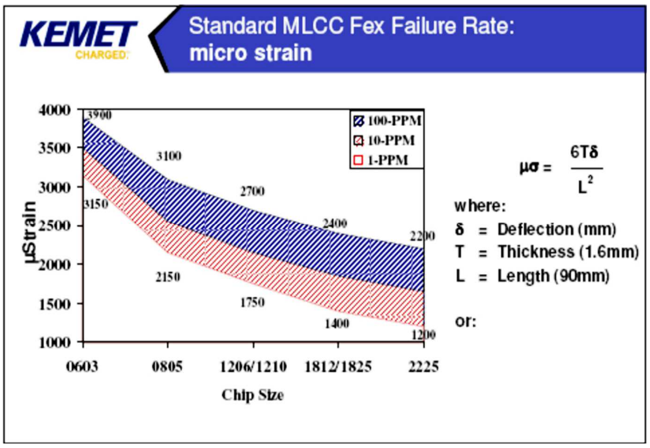

Fig. 4. KEMET-MLCC Fex Failure Rate [KEMET inc.]

Control of bending of the boards by measuring mechanical stress has proven to be a successful and well-accepted method for detecting and preventing damage in the manufacturing processes of the electronics industry. The multifunctionality of the modules determines an increased concentration of components, which in turn leads to an increase in the potential for damage. This requires a large number of PCB manufacturers to produce with certain limits on the stress levels imposed by customers and component suppliers. Mechanical stress measurement technologies use different methodologies, which makes it impossible to compare data and measurement results. The standard covers variations in the placement of sensors, their positioning, the design of the experimental installation, the data collected and the units of measurement. The measurement itself includes the placement of the sensors at the specified places on the board and the measurement of the deformation in the assembly process. Processes in which stress levels are above certain limits are considered dangerous, and corrective action should be taken immediately. In determining the tolerable levels of stress, the following factors are mainly taken into account:

• Manufacturer's specification stating the allowable stress levels related to the dimensions of the components – fig. 4.

• Permissible levels in accordance with the results of mechanical stress measurements in direct dependence on the stress rate / change in the absolute value of stress per unit time.

The relationship between the stress rate, the absolute value of the stress and the thickness of the board is shown in fig. 5.

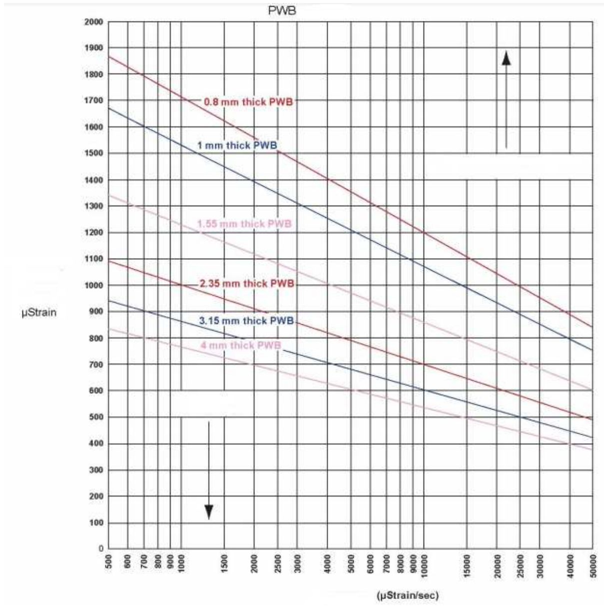

Fig. 5. Diagram of the stress rate, the absolute value of the stress and the thickness of the board [IPC/JEDEC-9704]

When a tensile force is applied to the material, normal stresses σ appear in it, which are related to the applied force. The extensions of the material shown in fig. 6 are directly proportional to the stresses.

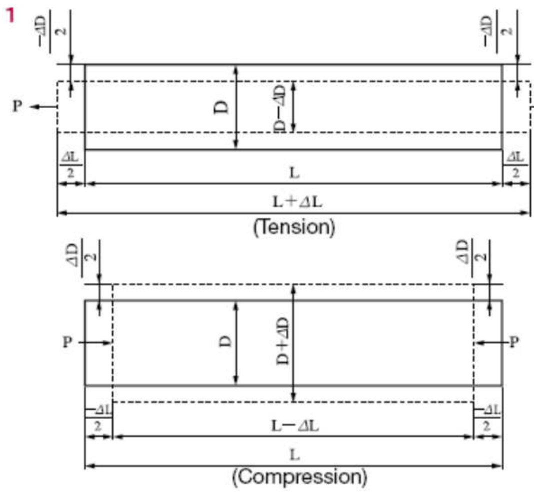

Fig. 6. Relationship between tension, stress and position [Vishey Beyschlag]

The ratio of the elongation to the original length is called the tensile stress:

$$\varepsilon = \Delta L / L \quad (1)$$

If the applied force is under pressure, then the ratio takes the following form:

$$\varepsilon = (-\Delta L)/L \quad (2)$$

The relationship between stress and tension is expressed through Hooke's law:

$\sigma = E.\varepsilon$, where ε is stress, E is modulus of elasticity, σ is internal stress

The specific resistance of the sensor increases (decreases) when it is subjected to tensile forces (pressure). The ratio of the change in resistivity to the original resistance is equivalent to the product of the voltage with the coefficient expressing the sensitivity of the sensor:

$$\Delta R/R=\Delta L/L.Ks=\varepsilon.Ks \quad (3)$$

For more accurate reading, the Wheatstone bridge shown in fig. 7, by which the changes of the resistances are transformed into changes of the voltages:

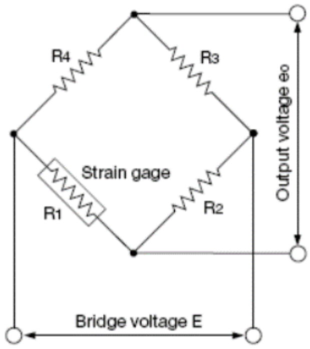

Fig. 7. Sensor connection diagram [Omega KFH Series]

Thus the output voltage is proportional to the change in resistance, ie. of the change of the applied forces (stresses):

$$e_0=\frac{(R_1.\Delta R).R_3-R_2.R_4}{(R_1+\Delta R+R_2)(R_3+R_4)}E=$$

$$\frac{1}{4}.\frac{\Delta R}{R}E=\frac{1}{4}.Ks.\varepsilon.E \quad (4)$$

The cables connecting the sensor and the measuring equipment must meet the following requirements:

• The choice of the appropriate type of cable is determined by the process in which the specific measurement is performed, with cables with PVC or Kynar insulation being preferred;

• The recommended cable length is 1.5 to 2.5 meters.

When measuring stress at variable temperatures, it is necessary to take into account the choice of the temperature coefficient of expansion of the sensor so that it coincides with that of the board.

When measuring stress, the measuring frequency, bitrate and signal level play a decisive role. All samples must be received and processed simultaneously in order to avoid calculation errors. It is recommended for correct measurement:

• For high speed processes, the minimum measurement frequency must be 500 Hz;

• For low speed processes, the minimum measurement frequency must be 100 Hz;

• Minimum resolution per sample - from 12 to 16 bits.

In the present experiment they are used:

1. Measuring interfaces KYOWA PCD 300A - 4 channels - 2 pieces;

2. HP Pavilion G6 / Intel Core i7 Notebook PC - 3.1GHz, 8Gb RAM;

3. Measurement software - PCD 30A;

4. Analysis software DAS 100.

III. RESULTS

They were used for the specific experiment:

• PCB with dimensions - 245x220x1,6mm;

• PCB type – FR 4 TG⩾150 C – multilayer;

• 4 modules per panel with 5 bridges with dimensions 4x2x1,6mm;

• Top and bottom board with dimensions 30mm, center board 24mm;

o Oven for soldering - Heller1809 MKIII N2;

o Transport width - 221mm, support - 110mm;

o Solderинг paste – INDIUM 5.8LS Type 3, SAC387;

o Nitrogen environment in the oven included;

o The set temperatures and thermal profile are shown on fig. 8.

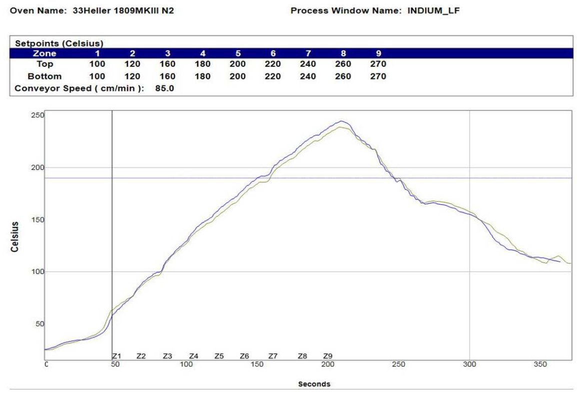

Fig. 8. Thermoprofile when soldering with paste INDIUM 5.8LS

A. POSITIONING THE SENSORS

In order to determine the positions and type of sensors for the processes selected for validation, the following should be considered:

• The sensor should cover a group of components or a presumed critical component;

• Determine the direction of the force and use a triaxial sensor in case of ambiguity;

• Evaluate the possibility of using the same sensor positions for several processes;

• Make sure that there are no support pins and other mechanical fastenings in the sensor areas.

The panelization and arrangement of the sensors of the experimental product (automotive) is shown in fig. 9.

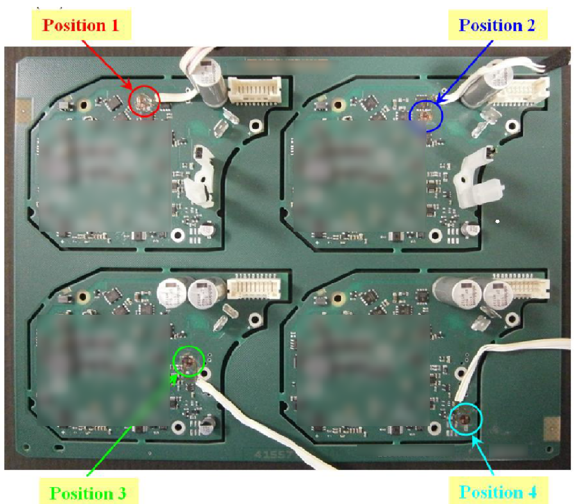

Fig. 9. Experimental panel with located sensors.

The following type of sensors were used for the specific measurements:

- KFG-1-120-D16-11L3M3S, Biaxial;
- - Length of the sensor - 1 мм;
- - Resistance (24˚, 50% RH) - 120.8 □, ± 0,4;
- - Correction factor (24˚, 50% RH) - 2.06 ± 1.0%;
- - Temperature coefficient + 0.008 %/˚C.

B. MEASUREMENT REZULTS

The measurement results are shown on fig. 10.

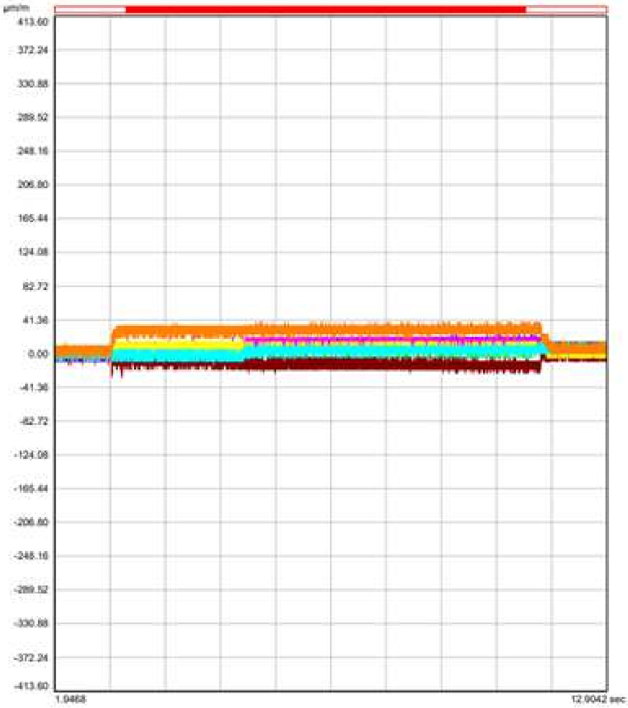

Fig. 10, Bending measurement results.

The maximum value of the deformation is 38,5 με.

C. ANALYSIS

According to the components used with size 0603 and the thickness of the printed circuit board, taking into account the requirements of fig. 4.5, the maximum deformation must not exceed 1000 με. During the measurement, a maximum value of 38.5 με was recorded for all monitored points. Therefore, the deformations at the critical points in the periphery of the single board and within the entire panel do not exceed the allowable ones. The many times lower value allows for future additional optimization of the availability of both elements within the board and the bridges in the panel.

IV. CONCLUSION

he requirements and methods for determining the stress in printed circuit boards in the process of their production are applied. Variants for determining the control points, fixing the sensors and measuring for a specific board and panel topology are presented. The results are for the assembly process to levels after soldering.

After many measurements and analysis of the results, we can assume that the described method is a necessary tool for prevention, as well as a method for locating and proving sources of mechanical stress.

ACKNOWLEDGMENT

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REFERENCES

[1] IPC A-610G, 2017.

[2] KEMET-MLCC Fex Failure Rate.// Thermo-mechanical Reliability of Lead-Free Solder Joints in Surface Mount Electronic Component Assembly (gre.ac.uk) open on 24.02.2021

[3] Valentin Tsenev; Valentin Videkov; Aleksei Stratev; Nikolay Georgiev, Improved soldering of components with different thermal masses by hybrid printing of solder pastes, 2017 40th International Spring Seminar on Electronics Technology (ISSE) Pages: 1 – 6 DOI: 10.1109/ISSE.2017.8000910

[4] https://interflux.com .

[5] IPC/JEDEC-9704, Printed Wiring Board Strain Gage Test Guideline, June 2005, A standard Developed by IPC, Bannockburn, IL.Design.

[6] Guidelines for Preventing Flex Cracking Failures in Ceramic Capacitors, 2016.

[7] Gary F. St.Onge.The Finer Points of Test, Evaluation Engineering, PP 36, 38-41, January 2006.

[8] PCD-300A HARDWARE INSTRUCTION MANUAL, PCD-300A/320A SENSOR INTERFACE CONTROL SOFTWARE PCD-30A INSTRUCTION MANUAL, DATA ANALYSIS SOFTWARE DAS-100A INSTRUCTION MANUAL - Kyowa Electronic Instruments, 2018.

[9] https://permacol.nl/nl/producten/lijm-voor-electronica/ open on 12.02.2021

[10] https://www.henkel-adhesives.com /technomelt/ . open on 10.01.2021

[11] Valentin Videkov, Slavka Tzanova, Radosvet Arnaudov, Nikolai Iordanov, New assembling technique for BGA packages without thermal processes, Microelectronics Reliability, Vol. 41, 2001, p. 611-615

[12] Valentin Videkov, Valentin Tsenev, patent 67290 B1 / /31.03.2021 Combined footprint for soldering.

[13] Valentin Videkov, Valentin Tsenev, patent 67291 B1 / 31.03.2021 Method for selective screen soldering

Според използваните компоненти с размер 0603 и дебелината на печатната платка, като се вземат предвид изискванията на фиг. 4,5, максималната деформация не трябва да надвишава 1000 με.