Proceedings of the 2020 International Conference on Information Technologies (InfoTech-2021), IEEE Conference, Rec # 52438

16-17 September 2021, St. St. Constantine and Elena, Bulgaria

Measurement of PCBA (Printed circuit board assembly) deformation during functional testing of electronic modules

1st Valentin Tsenev
College of Energy and Electronics
TU Sofia
Botevgrad, Bulgaria
vtsenev@tu-sofia.bg

2nd Valentin Videkov
Faculty of Electronic Engineering and Technologies
TU Sofia
Sofia, Bulgaria
videkov@tu-sofia.bg

3rd Nadejda Spasova
College of Energy and Electronics
TU Sofia
Botevgrad, Bulgaria
nadia.spasova@mail.bg

***Abstract*—With an intelligent measuring system, the PCBA (Printed circuit board assembly) deformation was prepared and measured during a functional test of a product. An area of critical deformation is defined based on the standards for testing in surface mounting. The used intelligent measuring system and its setting are described. The results of practical measurements of deformations during functional testing of a specific product 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*— measuring system, measurement, deformation, testing**

I. INTRODUCTION

Essential in the design of electronic modules for surface mounting [1] is the optimal location of the elements, which after mounting on a board do not lead to defects that reduce the reliability of the product. This design is strongly related to the requirements and limitations of production technologies (DFM [2]) and is a necessary condition for long-term stability in the operation of the products. In many cases, the rejection of the board is associated with the appearance of defects during assembly or subsequent failure associated with the assembly. The main contribution to the appearance of defects has the mechanical stress created during production, which leads to mechanical defects of the elements or the connections between them. Another part of the deformation is the result of the functional testing process.

The determination of the deformations in the specific case of functional testing, which is most often used in automotive electronics, are performed and analyzed in the present work. For this purpose, the standards IPC / JEDEC-9704 [3], KEMET-MLCC (Multilayer Ceramic Chip Capacitors) Fex Failure Rate [4] and a specific suitable measurement scheme with an intelligent measuring system are applied. Depending on the setting [5], the type of strain gauge and the measurement and impact scheme [6] are selected. Based on the standard, the results are evaluated and if they are critical, options are sought for a new arrangement of the elements on the board or their replacement with other types, it may even be necessary to change the geometry of the board and the material from which it is made.

II. EXPERIMENTS

A. Procedure

Applying the IPC / JEDEC-9704 standard, the specific stress test areas for assembled printed circuit boards are described. The test itself allows to make an objective analysis of the stress levels on SMD (Surface mount devices) components in the process of functional testing of assembled modules.

The application of standard procedures is a basic condition in serial production, but also essential for application in experimental samples. This is because it gives credibility to the methodology even when applied to several samples.

A KEMET-MLCC Fex Failure Rate diagram was used for the allowable stress levels at 1 ppm, 10 ppm, 100 ppm depending on the dimensions of the SMD components. In fig. 1 shows the diagram of KEMET and IPC / JEDEC-9704.

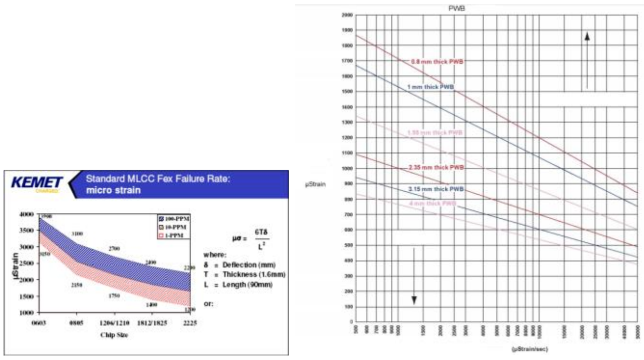

Fig. 1. KEMET-MLCC Fex Failure Rate [KEMET inc.] and diagram of the stress rate, the absolute value of the stress and the thickness of the board [IPC/JEDEC-9704]

By measuring mechanical stress, the bending of the boards is controlled and this method has proven to be well accepted for detecting and preventing damage in the production processes of the electronics industry.

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 on are directly proportional to the stresses in fig. 2.

The ratio of the elongation to the original length is called the tensile (stress) – fig. 2.:

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

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

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

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

σ=E.ε, 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 stress with the coefficient expressing the sensitivity of the sensor:

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

For more accurate reading, the Wheatstone bridge shown in fig. 2, by which the changes of the resistances are transformed into changes of the voltages.

Thus the output voltage is proportional to the change in resistance, ie. of the change of the applied forces (stresses) – fig.2.:

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

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

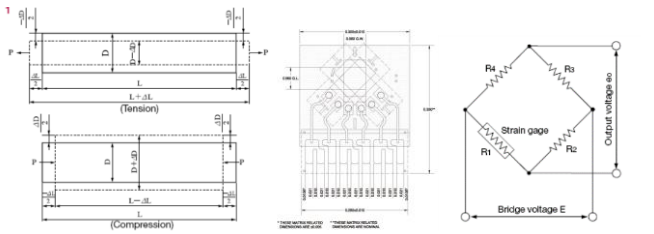

Fig. 2. Relationship between tension, stress and position [Vishey Beyschlag] and strain gauge with connection scheme in Wheatstone

B. Solution

After preparing the necessary documentation and the sequence of production processes defined in the flowchart, we proceed to determine the risk operations that will require validation by measuring mechanical stress.

Risky operations can be:

- Insertion connector;
- Attaching the board to the cover and screwing it with screws;
- Pin trough hole;
- Insertion in selective soldering frame;
- IC Test;
- Routing;
- Mechanical test;
- Functional test;
- Other assembly processes.

For the specific assessment of the deformations in a functional test of electronic modules, an algorithm and a block diagram of a validation procedure shown in fig. 3.

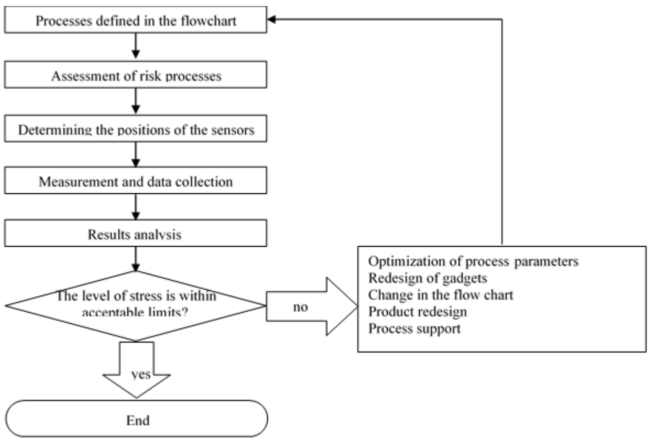

Fig. 3. Algorithm and block diagram of the validation procedure

They are used in the present work:

1. Measuring interfaces KYOWA PCD 300A - 4 channels - 2 pieces;
2. HP Pavilion G6 PC /Intel Core i7 – 3.1GHz, 8Gb RAM/;
3. Measurement software - PCD 30A;
4. Analysis software DAS 100.

The described intelligent measuring system is shown in fig. 4.

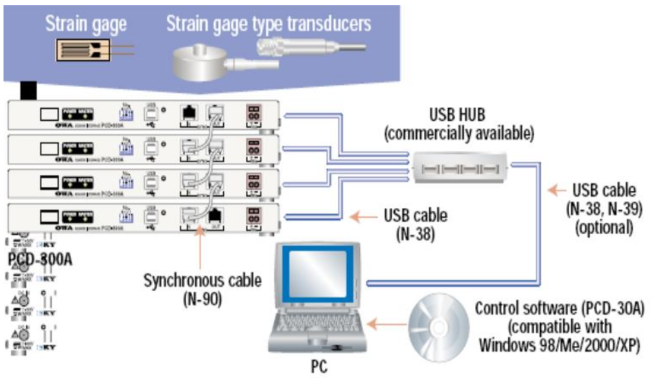

Fig. 4. Intelligent measuring system

The following objects were used for the specific experiment:

- electronic module (automotive) – fig. 5.;
- PCB – FR 4 TG⩾150 C – multilayer.

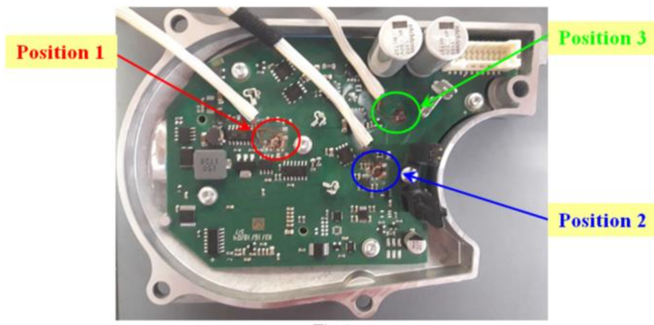

Fig. 5. Fixed module with strain gauges

In order to determine the positions and type of sensors for the functional testing process 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;

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

For the specific measurements, the mounted sensors shown in fig. 6. with the following specification:

1. Triaxial strain gauges:
   - KFG-1-120-D17-11L3M3S, Triaxial;
   - Length of the sensor - 1 мм;
   - Resistance (24˚, 50% RH) – 120.0 **Ω**, ± 0,4;
   - Correction factor (24˚, 50% RH) - 2.09 ±1.0%;
   - Temperature coefficient + 0.008 %/˚C.
2. Biaxial strain gauges:
   - KFG-1-120-D16-11L3M3S, Biaxial;
   - Length of the sensor - 1 мм;
   - Resistance (24˚, 50% RH) – 120.8 **Ω**, ± 0,4;
   - Correction factor (24˚, 50% RH) - 2.08 ±1.0%;
   - Temperature coefficient + 0.008 %/˚C.

Fig. 6. Triaxial and biaxial strain gauges

Details of the measurement in the functional testing are:

1. Measurement frequency – 5000 Hz
2. Functional test head – fig. 5.
3. Sequence of actions:

• Step 1 - Inserting the module in the tester socket - fig. 7.

• Step 2 - Testing - fig. 7.

Fig. 7. Tester and testing of electronic module

The PCD 30A measurement software is designed to control, visualize and control a maximum of four PCD 300A and PCD 320A interfaces, the recognition of which is shown in fig. 4 and the channel selection is shown in fig. 8 and 9:

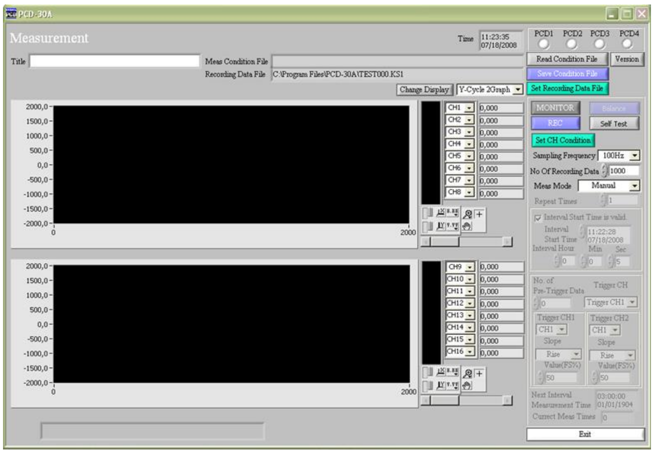

Fig. 8. Setup window

The measurement control unit and the channel tuning dialog box are shown in fig. 9.

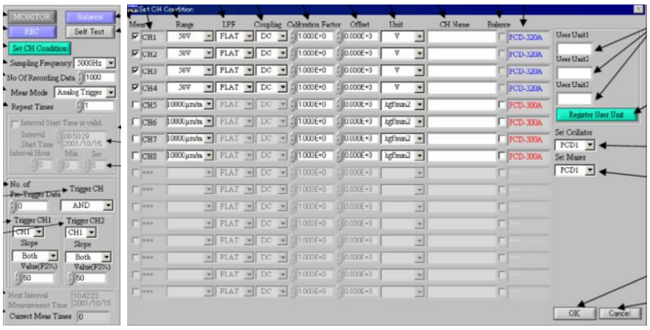

Fig. 9. The measurement control unit and the channel tuning dialog box

In fig. 10 shows the algorithm of the used interval measurement.

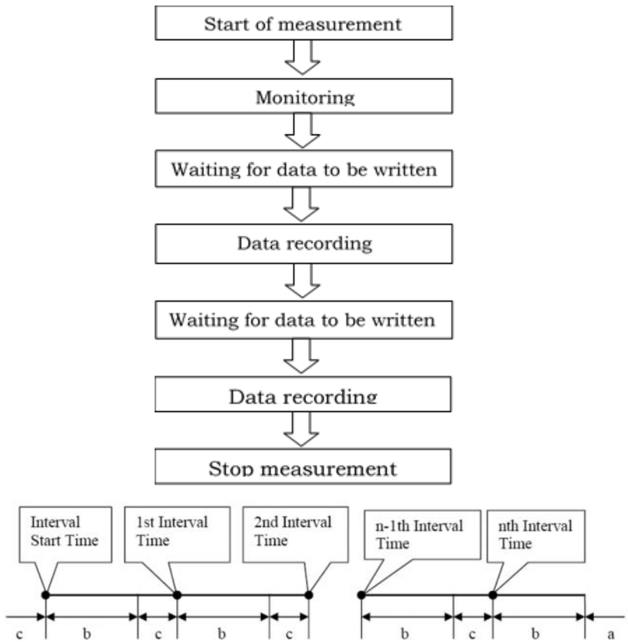

Fig. 10. Interval measurement algorithm

III. Results

A. *Measurement results*

The measurement results are shown in fig. 11.

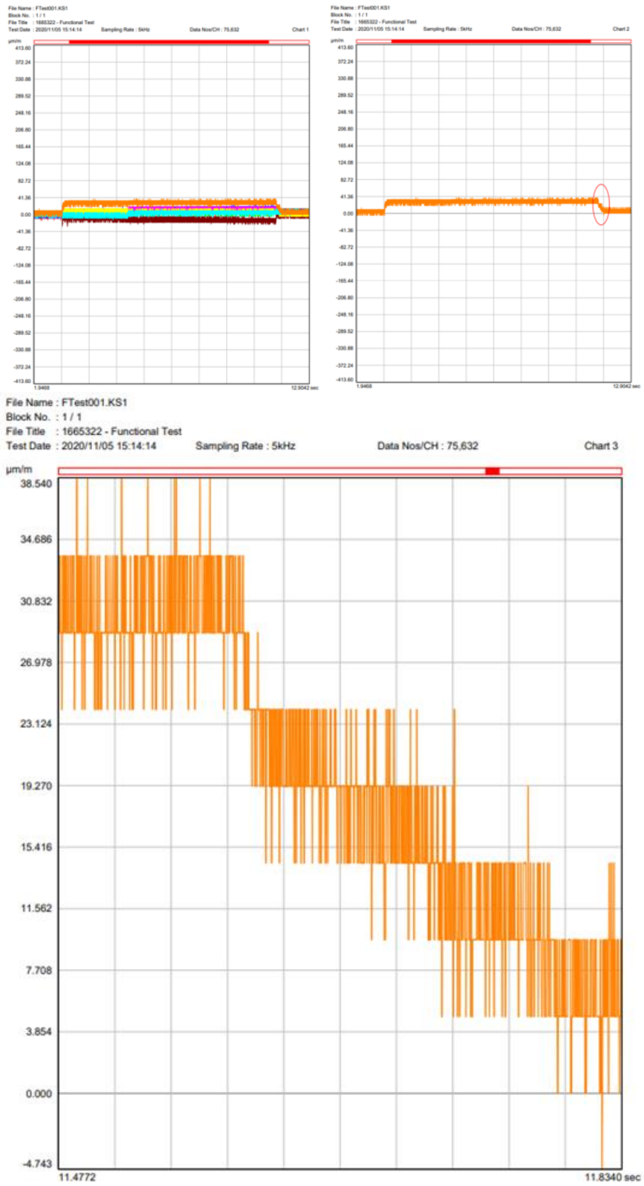

Fig. 11. Bending measurement results

In fig. 11. chart 1 shows the results of the deformation measurement in the functional test on channels in different colors, as shown in fig. 5 and fig. 6. Fig.11 chart 2 shows the result of the maximum measured force of channel 8 of strain gauge 3. Fig.11 chart 3 shows in detail the measurement result of channel 8 of strain gauge 3. The measured values of deformation reach maximum levels of 38 , 5 με.

B. *Analysis*

The components used have a minimum size of 0603 and according to fig. 1. at 100 ppm the stress rate must be below 4000 με/s. According to the PCB thickness of 1.6 mm and the determined stress rate of 4000 με / s, according to the graph in fig. 1, the maximum deformation should not exceed 1000 με. During the measurement, a value of 38.5 με was reached. Therefore, the deformations at the critical points in the periphery of the single board 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.

In fig. 11 chart 2 and 3 show the dynamics of deformation change during the whole process of functional testing. There is a background of 5 με and peaks with an amplitude of 15 με, as well as deformation in both directions - brown and other graphs of fig. 11 chart 1. Behavior is different in different directions. The applied functional testing process lasts 8 seconds.

IV. Conclusion

The requirements and methods for determining the stress in printed circuit boards in the process of manufacturing electronic modules are applied. A variant for determining the control points, fixing the sensors and measuring the deformation in a specific board and panel topology is presented.

After the measurements and analysis of the obtained 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. The significant reserve in the mechanical construction allows some of the results to be applied in the development of technologies for installation of modules with three-dimensional orientation and in some cases of bending elements.

For the specific process of functional testing, the behavior in time, which can be seen in fig. 11 chart 3. There is a background with an amplitude of 5 με, which is caused by the process of a single puncture and which depends on the contact pins used. Peaks are also observed, which are caused by the successive insertion of the contact needles. It is necessary to take into account the complex interaction of the individual peaks.

Acknowledgment

This research has been supported by European Regional Development Fund within the Operational Programme "Science and Education for Smart Growth 2014-2020" under the Project CoE "National Center of Mechatronics and Clean Technologies", Contract No. BG05M2OP001-1.001-0008.

This research is supported by the Bulgarian FNI fund through the project "Modeling and Research of Intelligent Educational Systems and Sensor Networks (ISOSeM)", contract КП-06-Н47/4 from 26.11.2020.

References

[1] Guidelines for Preventing Flex Cracking Failures in Ceramic Capacitors, january.2003.

[2] DFM VALEO, 2016.

[3] IPC/JEDEC-9704, Printed Wiring Board Strain Gage Test Guideline, June 2005.

[4] KEMET-MLCC (Multilayer Ceramic Chip Capacitors) 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.

[5] Gary F. The Finer Points of Test, Evaluation Engineering, 2006.

[6] 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, 2006.