Measurement with intelligent measuring system of PCB deformation when separating modules from a panel

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***Abstract*—By using an intelligent measuring system, the necessary preparation and measurement of the deformation of the PCB during the separation of the module (board with mounted electronic components) from the panel was performed. An area of critical deformation is defined based on the standards for testing in surface mounting. The results of practical measurements of deformations after separation of modules from panels 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—rutting, measuring system, measurement, deformation, testing

I. INTRODUCTION

Essential in the design of a panel with boards for surface mounting [1] is the optimal location of the appropriate elements (bridges, V-cut), which hold the boards to the panel and after mounting the elements are removed to separate the boards from the panel. 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 failure of the board is associated with the appearance of defects during installation or subsequent failure associated with the installation. A significant 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. Part of the deformation is the result of the process of separating the boards from the panel (rutting, breaking, cutting, punching.

The determination of the deformations in the specific case of separation of boards from a panel by ruting, 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 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 additional mechanical strengthening by changing the construction of the panel or the elements used. The same methodology is applied to other ways of separating boards from panels.

II. EXPERIMENTS

A. Applicability

Multilayer ceramic capacitors (MLCCs), BGA and all SMT components are sensitive to mechanical deformation in the manufacture of electronic modules. One of the causes of defects in MLCCs, BGA, SMT is excessive bending, which causes defects, as shown in fig. 1.

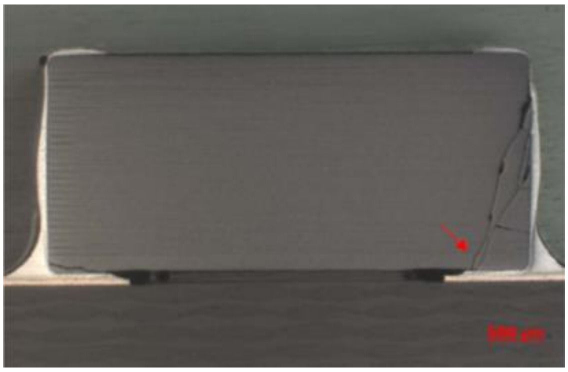

Fig. 1. Damaged capacitor during handling

The measurement of mechanical stress on circuit boards can be represented as shown in fig. 2.

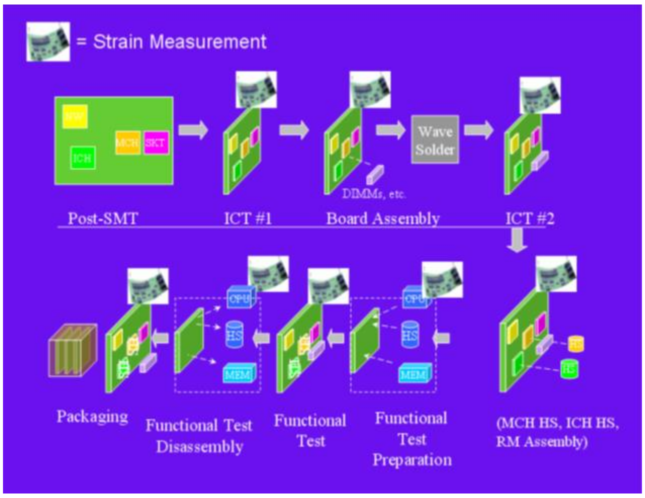

Fig. 2. Measurement of mechanical stress during circuit assembly

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The IPC / JEDEC-9704 standard describes the specific guidelines for stress testing of assembled printed circuit boards. The test itself allows to make an objective analysis of the levels of impact on SMT components, during the process of separating assembled boards from a panel.

A KEMET-MLCC Fex Failure Rate diagram was used for the allowable stress levels at 10 ppm and 100 ppm depending on the dimensions of the SMT components, shown in fig. 3.

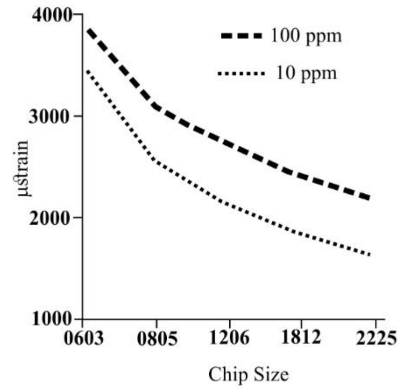


Fig. 3. According to data from KEMET-MLCC Fex Failure Rate [KEMET inc.]

By measuring mechanical stress, the bending of the boards is controlled and this method has established itself as well accepted for detecting and preventing damage in the production processes of the electronics industry. Mechanical stress measurement technologies use different methodologies, which makes it impossible to compare data and measurement results. The standard covers variations in sensor placement, positioning, experimental setup design, data collected and units of measurement.

The relationship between the stress rate, the absolute value of the stress and the thickness of the board is shown in fig. 4.

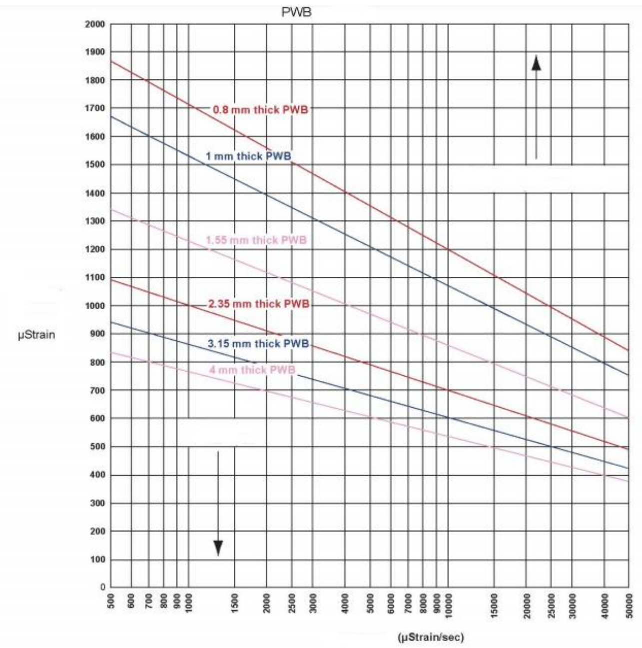


Fig. 4. Diagram of the stress rate, the absolute value of the stress and the thickness of the board [IPC/JEDEC-9704]

When a tensile force is applied to the material, normal stresses σ appear in it, which are related to the applied force. As shown in [Vishey Beyschlag] the ratio of elongation to the original length is called the tensile stress:

$$\varepsilon=\Delta L/L \tag{1}$$

where ΔL is the relative elongation and L is the initial length.

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

$$\varepsilon=(-\Delta L)/L \tag{2}$$

The connection 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 voltage with the coefficient expressing the sensitivity of the sensor:

$$\Delta R/R=\Delta L/L.Ks=\varepsilon.Ks \tag{3}$$

B. Decision

In fig. 5. the scheme and type of the strain gages KFG-1-120-D16-11L3M3S used are shown.

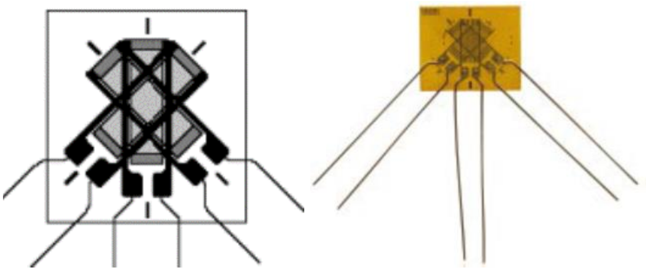


Fig. 5. Strain gauge KFG-1-120-D16-11L3M3S

For more accurate reading, the Wheatstone Bridge shown in fig. 6., through which the changes of the resistances are transformed into changes of the voltages.

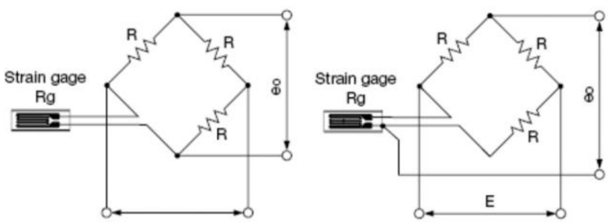


Fig. 6. Sensor connection diagram [Omega KFG Series]

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

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

$$\frac{1}{4}.\frac{\Delta R}{R}E = \frac{1}{4}.Ks.\varepsilon.E \tag{4}$$

When measuring stress, the frequency of measurement, the bit rate and the new signal play a decisive role. All samples must be received and processed simultaneously in order to avoid calculation errors.

C. Samples

In the present experiment, surface mounting elements mounted on four-layer printed circuit boards with lead-free solder by convection soldering according to the instructions given for the applied paste were used. Heller 1809 furnace was used. A similar profile can be realized by conductive soldering in semi-automatic mode with Tresky 3002 PRO, for single-sided installation. It was used to determine stress :

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

The following objects were used for the specific experiment:

- PCB - 245x220x1,6mm;
- PCB type – FR 4 TG⩾150 C – multilayer;
- 4 modules on a panel with 5 bridges with dimensions 4x2x1,6mm;
- Top and bottom board with dimensions 30mm, center board 24mm.

In order to determine the positions and type of sensors for the selected PCB separation process, 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.

Measurement details for depanelization are:

1. Measurement frequency – 2000 Hz;
2. Routing System - Elite EM-5700N - fig. 7.;
3. Routing Fixture - fig. 7.;
4. Routing process parameters:
   - Routing bit diameter - 2.0mm;
   - Spindle speed - 30000 RPM;
   - Feed rate- 15mm/s.
5. Sequence of cutting from the point of view of measuring the deformation, taking into account the proximity of critical components - fig. 7.

The panelization and arrangement of the sensors, as well as the machines and tools used in the experimental device are shown in fig. 7.

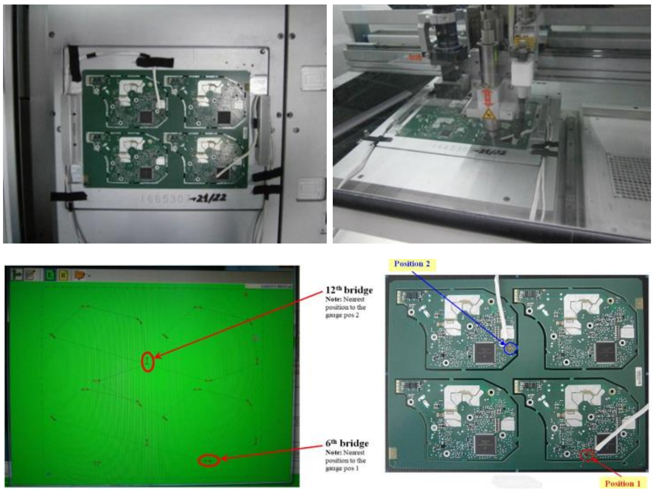


Fig. 7. Experimental panel with located sensors

For the specific measurements, the mounted sensors shown in fig. 8. with the following specification:

- KFG-1-120-D17-11L3M3S, Triaxial;
- Length of the sensor - 1 mm;
- Resistance (24˚, 50% RH) - 119.6 **Ω**, ± 0,4;
- Correction factor (24˚, 50% RH) - 2.06 ±1.0%;
- Temperature coefficient + 0.008 %/˚C.

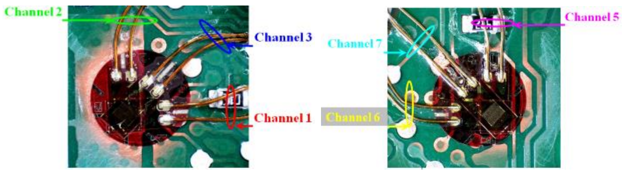
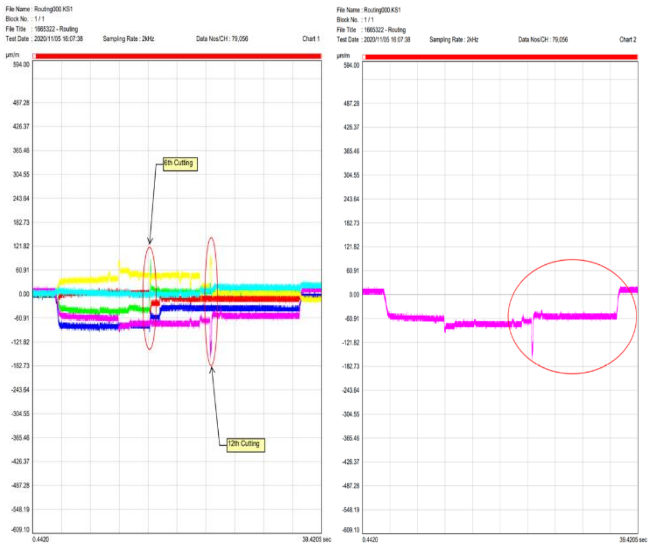


Fig. 8. Experimental panel with located sensors

III. Results

A. Measurement results

The measurement results are shown in fig. 9.



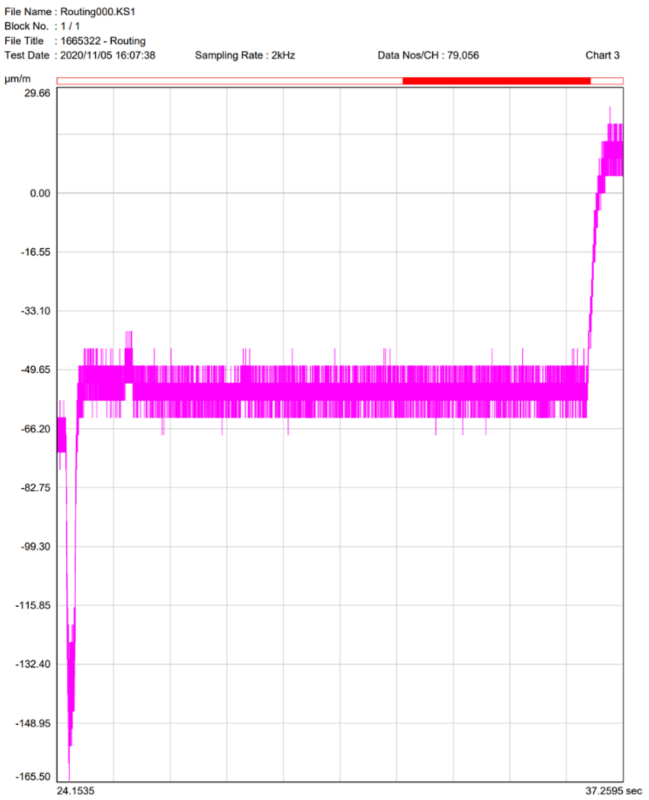


Fig. 9. Bending measurement results

In fig. 9. chart 1 shows the results of measuring the deformation when cutting 2 bridges per panel on channels in different colors, as shown in fig. 7 and fig. 8. Fig.9 chart 2 shows the result of the maximum measured force when rutting a bridge 12. Fig.9 chart 3 shows in detail the result of measuring a bridge 12. The measured values of deformation reach maximum levels when cutting a bridge 12 - fig. 9 chart 1, 2 and 3 and have reached a maximum value of 165.5 με.

B. Analysis

The components used have a minimum size of 0603 and according to fig. 3. 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. 4, the maximum deformation should not exceed 1000 με. A value of 165.5 με was reached during the measurement. Therefore, the deformations at the critical points in the periphery of the single board do not exceed the allowable ones. The much lower value allows for future additional optimization of the availability of both elements within the board and the bridges in the panel.

In fig. 9 charts 2 and 3 show the dynamics of deformation change during the whole cutting process for separating boards from a panel with rutting. There is a background of 15 με and peaks with amplitude from 40 με to 100 με, as well as deformation in both directions - the yellow and other graphs of fig. 9 chart 1. There are directions in which no peaks are observed - the light blue graph of fig. 9 chart 1. Behavior is different in different directions. The applied rutting separation process lasts 39 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 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.

For the specific process of separating boards from a panel with rutting, the behavior in time, which can be seen in fig. 9 chart 3. There is a background with an amplitude of 15 με, which is caused by the cutting process and which depends on the tools and cutting modes used. This background can be studied under different conditions and optimized with the development of tools and cutting modes. Peaks are also observed, which are caused by the design and materials of the entire supporting system of the electronic module in the panel. Their future research is interesting for the creation of design rules for optimal constructions of panels in terms of deformation forces, the requirements for which are to be greatly reduced with the use of small elements and increase the requirements for high reliability.

Acknowledgment

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