Comparative analysis of the measured deformation of PCBA (Printed circuit board assembly) in the production of electronic modules

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Abstract—**Based on the flow chart for the production of electronic modules, the most frequently used operations are determined and the preparation, measurement and analysis of the stress of the components mounted on a specific board are made. After comparing the results in statics (maximum stress), dynamics (background stress and its development over time) and during (the time during which they are subjected to stress), conclusions are made about the most dangerous operations for damage to components of applied mechanical stress. In the conclusion the admissibility of the obtained deformations and the risk of using the described processes are assessed.**

Keywords— ***electronic modules, manufacturing process, measurement, deformation, comparative analysis***

I. INTRODUCTION

Essential in the production of electronic modules is the optimal design for long-term reliability. The main reasons leading to defects in the board are related to the appearance of defects in electronic installation [1]. The appearance of defects is a result of mechanical stress during the installation processes [2]. These defects reduce the reliability of the modules both during the installation process and during their operation.

In Fig. 1. a diagram of the main processes in the production of electronic modules is shown.

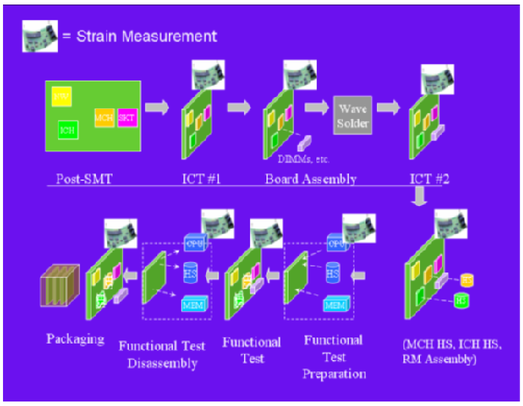

Fig. 1. Basic processes in the production of electronic modules [2]

The production processes are related to the processing of a panel with many boards and individual boards. Panel processing is preferred because parallel processing reduces unit costs.

Determining the deformations in the specific case through the application of appropriate tests and their analysis are an important condition for the future reliability of the products. Nowadays, the most commonly applied standards [3, 4] and a specific measurement scheme. Depending on the studied process [5], the type of strain gauge and the scheme of measurement and impact are selected [6]. Through analysis of the obtained results, evaluation, validation and, if necessary, improvement of the respective process is performed.

II. TEST SET-UP

A. *Procedure, measuring system used and object examined*

The present experiment uses the IPC / JEDEC-9704 standard [3] for evaluation, 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 the components during the assembly processes of electronic modules using the KEMET-MLCC Fex Failure Rate diagram [4] for the allowable stress levels at 100 ppm defects, depending on the dimensions of SMT components, which in this case are size 0603.

The calculations for the specific measurement refer to the Vishey Beyschlag method [7], and the relationship between stress and tension is expressed by Hooke's law [8].

Biaxial strain gauges and KYOWA PCD300A hardware, PCD 300A measuring interface, PCD 30A control software, DAS 100A analysis software were used for the preparation and implementation of the stress measurement experiments. CC-33A glue was used for gluing.

The circuit board, materials and technological equipment used are:

- PCB with dimensions 245x220x1.6 mm, FR4, TG⩾ 150 C, multilayer, 4 modules on a panel with 5 bridges with dimensions 4x2x1.6 mm, upper and

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lower board with dimensions 30mm, central board with size 24mm, shown in Fig. 2.;

- Heller 1809 MKIII N2 soldering furnace with nitrogen;
- Soldering paste INDIUM 5.8LS, Type 3.

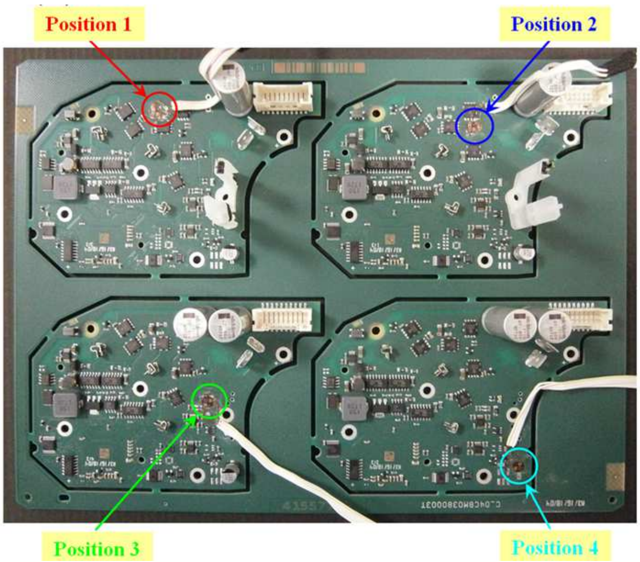

Fig. 2. Experimental panel with located moduls and sensors

B. *Solution*

In this particular solution, an algorithm for the validation procedure shown in Fig. 3.

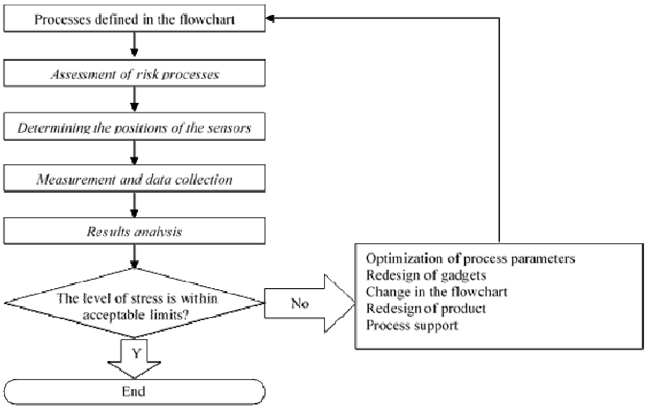

Fig. 3. Algorithm of the process validation procedure

This algorithm provides a closed procedure that leads to a positive result.

The following validation operations were defined for the specific case:

- Parametric testing (ICT)
- Separation of boards from a panel by rutting
- Assembly in a box with a screw
- Functional test

Stress measurement was performed under the following conditions:

1. Measurement frequency - 2000 Hz for separation and assembly operations and 5000Hz for testing operations;
2. Operating temperature and humidity - from 0 to 40°C and from 20 to 85% RH;
3. Bridge exciter - sinusoidal voltage 2V AC rms 1kHz.

III. RESULTS

A. *Measurement results*

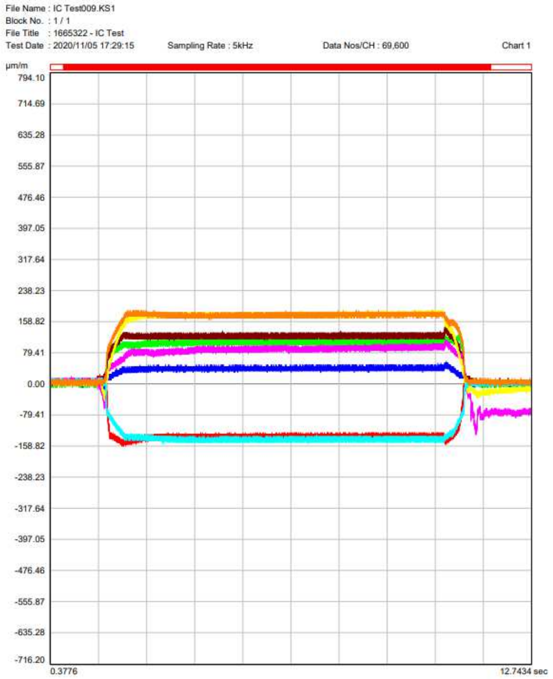

Fig. 4. Measurement results at ICT

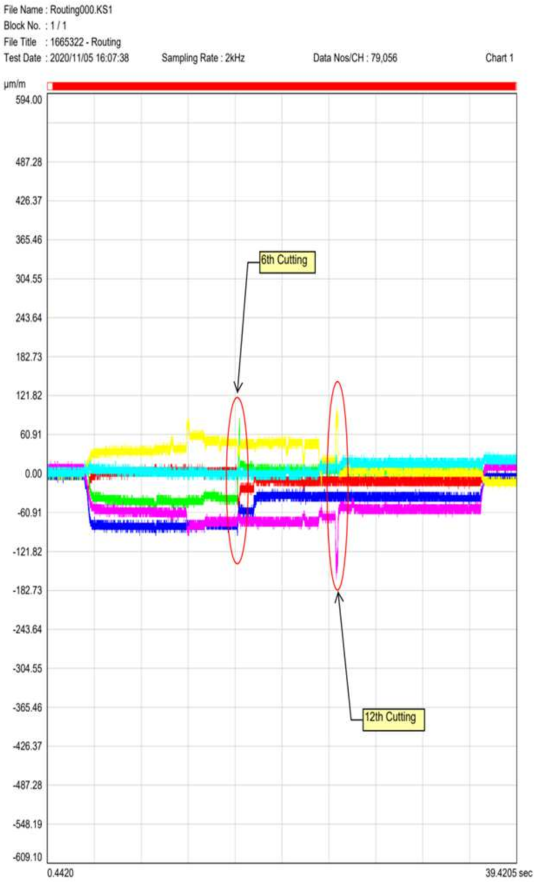

Fig. 5. Measurement results at depanelization

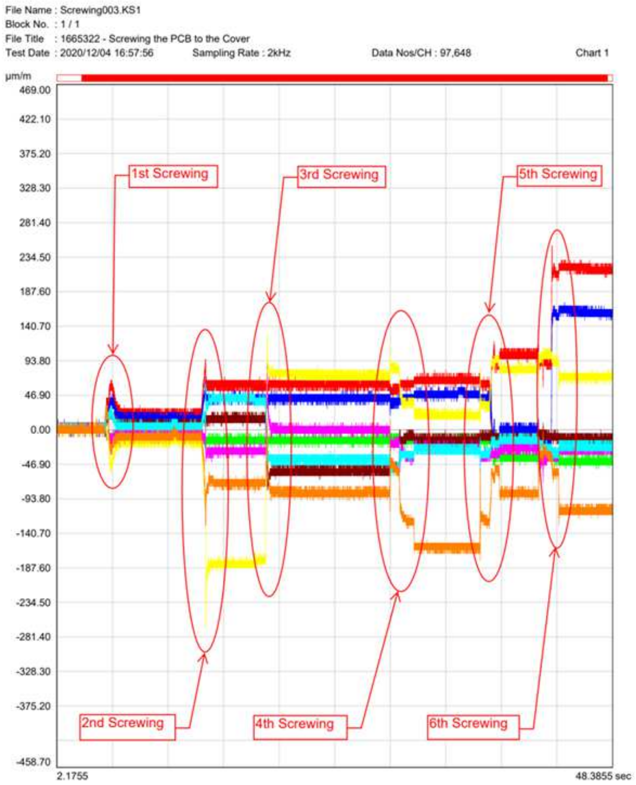

Fig. 6. Measurement results at assembly

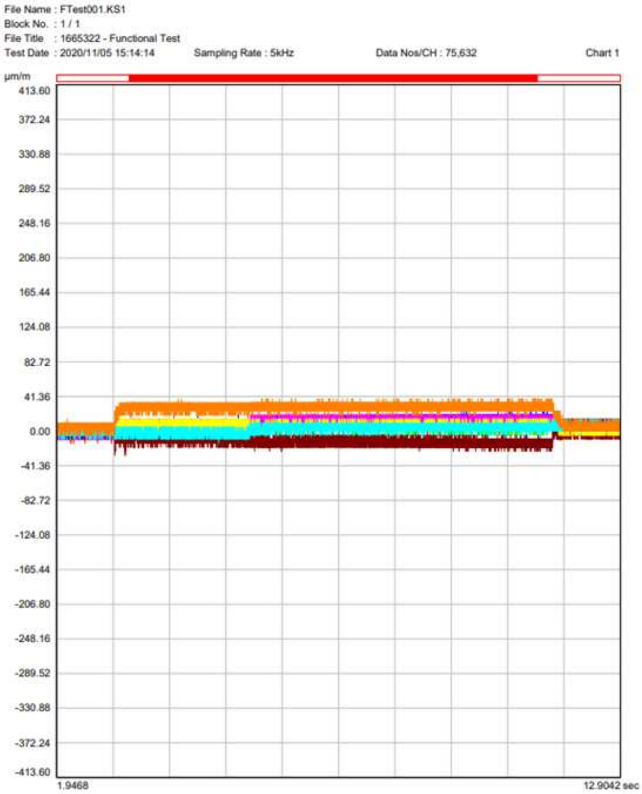

Fig. 7. Measurement results at FT

In Fig. 4, 5, 6, 7. The obtained measurement results for the four studied processes are shown - respectively parametric testing, separation of boards from a panel, assembly in a box with a screw assembly and functional testing.

TABLE 1. PAGE LAYOUT DESCRIPTION ИМЕ

Comparative analysis of measured stress

Operation	**ICT**	**Depanelisation**	**Assembly**	**FT**
Stress time, s	9	39	**55**	8
Maximum stress, με	186.9	165.5	**269.2**	38.5
Background stress, με	**50**	15	20	5

B. Analysis

The maximum value of the deformation is 269.2 με and was measured under stress the impact of assembling a board mounted with components in a box with a screw assembly. The maximum stress response time is 55 s in the same process. The maximum dynamic stress (stress applied continuously throughout the process) is 50 με and is measured under the stress effect of parametric testing of a circuit board.

According to [3, 4] and the specification of the board (1.6 mm thickness) and the components used (size 0603), the maximum deformation should not exceed 1000 με. During the measurement, a maximum value of 269.2 με was recorded for all monitored points. Therefore, the deformation at the critical points is significantly lower than the requirements of the standard.

The obtained results allow for future additional optimization of the location of elements within the board, as well as the design of the panel in the absence of danger of reducing the reliability of the product.

The following conclusions can be drawn from the obtained results:

- Testing processes generate stress, which is greater when testing large areas and when testing with more contact needles (parametric test) (Fig. 4.) versus functional test (Fig. 7.);
- The processes related to mechanical impact (separation, assembly, etc.) have a strong and multistage effect, as in the separation processes the stress decreases in the next steps, and in assembly it is the opposite - the stress increases in the next steps - Fig. 5, 6;
- Multistage processes generate a higher risk of stress;
- Panel processing processes (large area components) are more critical in terms of stress generation and should be controlled and taken into account in preventive and predictive pre-work (FMEA (Failure Mode and Effect Analysis), DFM (Design for Manufacturing) and other) - Fig. 4, 7;
- The duration of stress exposure during technological operations is related to the duration of the operation and should be taken into account when using components with critical characteristics for reliability under the influence of stress for a longer time - electromechanics, sensors and others;

- The duration of stress in multistage processes is longer and should be taken into account in the design of product manufacturing technology;
- Dynamic stress is constantly acting and is superimposed on the static, which must be taken into account in the impact analysis;
- Dynamic stress is highest when processing large area components;
- The frequency of dynamic stress must be taken into account in order not to resonate with certain components, which would lead to a decrease in their reliability;
- Reducing the amplitude and frequency of dynamic stress is an important condition to avoid the risk of reducing the reliability of the products.

IV. CONCLUSION

The requirements and methods for determining the stress in printed circuit boards during the process of saturation and assembly are applied. Examples are presented for determining the control points, fixing the sensors and measuring at a specific board and panel topology. The results are for the process of complete production of an electronic module.

After measuring and analyzing the results obtained, 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.

In the future, research on the dependence of the generated stress in the various operations for the production of electronic modules on:

- Contact needles used in testing - contact crown, contact force, number of needles used and others;
- Routing modes - revolutions of the cutting tool, the type of cutting surface, the direction of movement of the cutting tool, the movement of the cutting tool and others;
- Screwing modes for screw assembly - turning speed, movement of the turning tool, type of the head of the turning tool, fixing of the board and others;
- Impact through stress on the components using other processes - working with frames, cleaning processes, thermal processes, blowing, automatic movement with grip, processes to compensate for bending of the boards, supporting and fixing the boards and others.

It will be positive to create design rules to reduce stress when creating a flow chart and operating modes for the production of electronic modules and products and, accordingly, the ability to use stress-critical components.

One approach may be the application of micromodules that reduce the size of the product, as well as the use of fewer elements with microassembly. During the testing, the possibility of parallel-sequential contact in order to separate the mechanical stress can be investigated.

For specialized products with critical values and requirements, it is possible to apply multi-stage installation with fixing by pouring into the housing.

ACKNOWLEDGMENT

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