

Thermal-Structural Coupling Analysis of PCBA System

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Abstract. In this paper, the thermal and structural analysis of the PCBA system is provided by using the 3-D ANSYS package. The results of thermal and structural analysis for complex and simple model are compared. The paper also describes the deformation analysis of the PCBA system components, and the weak components sensitive to thermal stress are determined through thermal-structural analysis. The results of thermal analysis are helpful to the optimizing overall arrangement design of PCBA system.

1. Introduction

With increasing miniaturization and multifunction of modern electronic products and devices, thermal reliability research should be done both in the research and design process and in mass production to ensure the quality and reliability of products [1]. The research on thermal failure analysis plays an important role in process improvement, incoming material and design [2].

As the heart of device, PCBA (Printed Circuit Board Assembly) system used surface mounting technology (SMT) on the empty board is widely applied to computers and related products, communications products and consumer electronics. The temperature, produced during PCBA working, results to the thermal-stress of the electronic device, and has effects to the parameters and lifetime of the PCBA system [3-4]. The modern electronic product becomes lighter, thinner, shorter and smaller. The increasing consumption of power has led to the significant increase in power densities of modern electronic equipment. So, overheating problem is paid more and more attention [5-6]. If do not pay attention to the thermal management of electronic equipment during the design period, the large amount of heat generated by the electronic device would not be under the control, therefore the product's reliability may be affected and lead to deteriorate the system stabilization or even make the whole system disabled.

Using ANSYS parameter design language (APDL), we build the entity model of PCBA system and divide the grid and heat transfers mainly by heat conduction, so their thermal radiations can be ignored. Frontal sample layout of PCBA system and finite element model are shown in Fig.1(a,b).



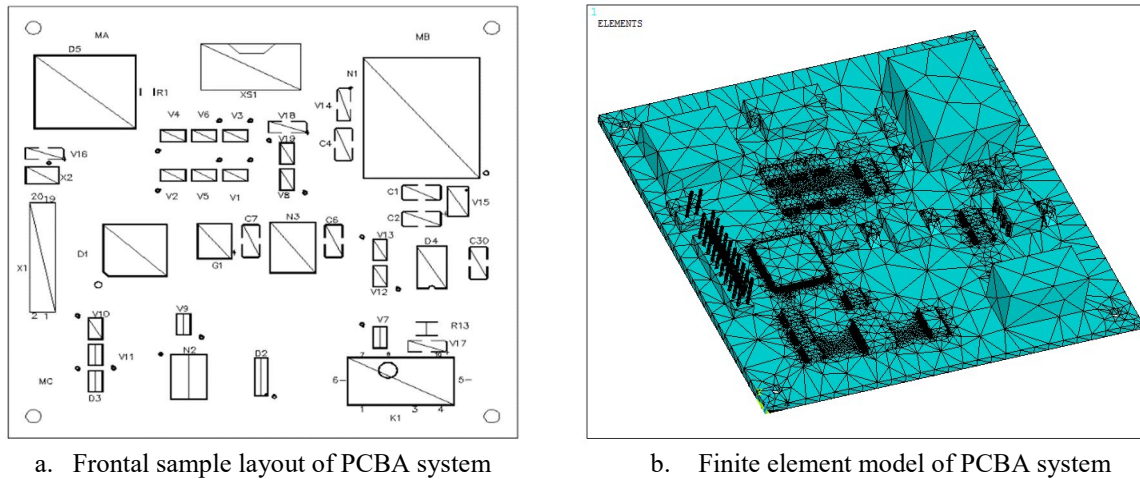


Figure 1. Layout and model of PCBA system

The structure of PCBA system is complicated, in order to ensure the accuracy of the calculation and speed up the convergence time. The sequentially coupled physics analysis is adopted in thermal-structural analysis. The result of the first physical analysis is the load of the second physical analysis and the basic physical load is the nominal boundary condition. [7]

2. Transient thermal analysis

The thermal analysis unit PLANE55 and SOLID87 are used to solve the temperature field. Transient thermal analysis is used for calculation of analysis on the time-dependent temperature field

and other parameters. Thermal balance equation Eq. (1) shows that the required heat of heating up object should be balanced against heat introduced into body and heat generated within object. In the equation, $T(x, y, z, t)$ expresses temperature field, ρ expresses material density, c expresses failure rate function, t expresses time, k_x, k_y, k_z expresses coefficient of heat conduction, Q expresses heat source density.

Thermal storage effect should be considered in transient analysis, matrix form might look like the following equation Eq.(2). In the equation, $(C)\{\dot{T}\}$ expresses thermal storage effect.

$$\rho c \frac{\partial T}{\partial t} - \frac{\partial}{\partial x} \left[\kappa_x \frac{\partial T}{\partial x} \right] - \frac{\partial}{\partial y} \left[\kappa_y \frac{\partial T}{\partial y} \right] - \frac{\partial}{\partial z} \left[\kappa_z \frac{\partial T}{\partial z} \right] - \rho Q = 0 \quad (1)$$

$$(C)\{\dot{T}\} + (K)\{T\} = \{Q(t)\} \quad (2)$$

Temperature field distributions of PCBA system at 180s is showed in Fig.2. Environmental temperature is 17°C and the calculated distributions of PCBA at various time can be obtained while there is power to the system.

Average temperature distributions of main devices are showed in Table 1. D_1 expresses microcontroller, N_1 expresses DC/DC power model, G_1 expresses crystal oscillator, N_3 expresses Three-terminal voltage regulator, D_4 expresses time-base circuit.

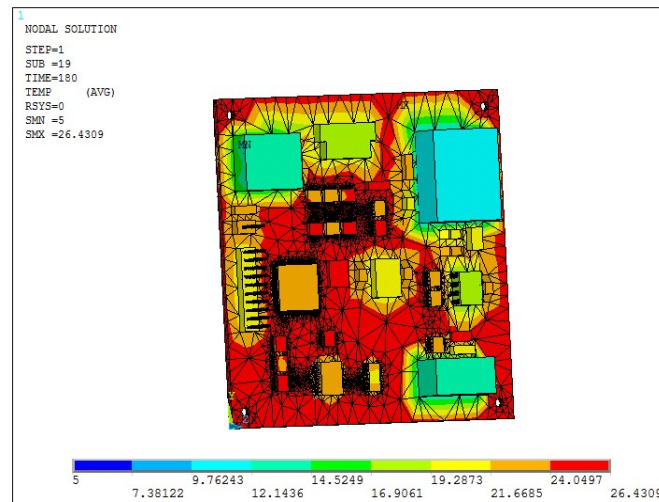


Figure 2. Temperature distribution at 180s

Table 1. Average temperature distributions of main devices

Time(s)	D1(°C)	N1	G1	N3	D4
60	19.2	29.4	22.1	21.9	21.7
180	25.2	32.7	23.7	23.1	22.4
300	26.9	33.4	24.0	23.6	23.3

3. Transient thermal stress and strain analysis

The obtained node temperature is applied to the model as a body load and then the structural stress is analysed. The hot element is converted into a responsive structural element and the results of thermal analysis are applied to each node as thermal load. At last, the corresponding thermal-structure coupling analysis results are obtained.

Uneven temperature distribution can lead to thermal stress in the components, According to the initial conditions, the external environment temperature is 17°C. Calculation result of thermal stress and at thermal strain 180s is shown in Fig.3 and Fig.4.

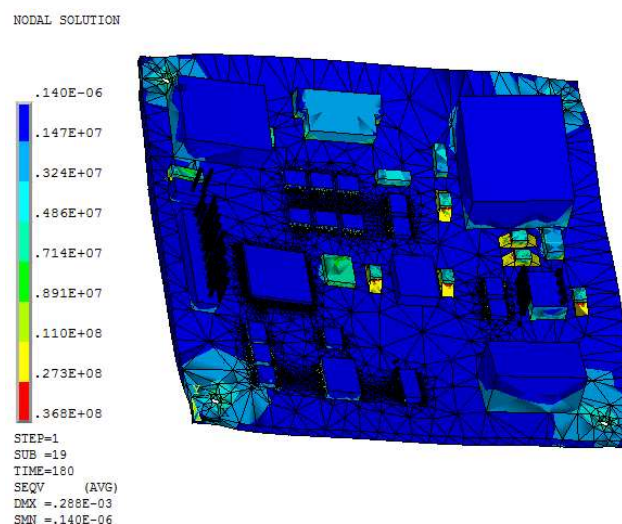


Figure 3. Thermal stress distribution at 180s

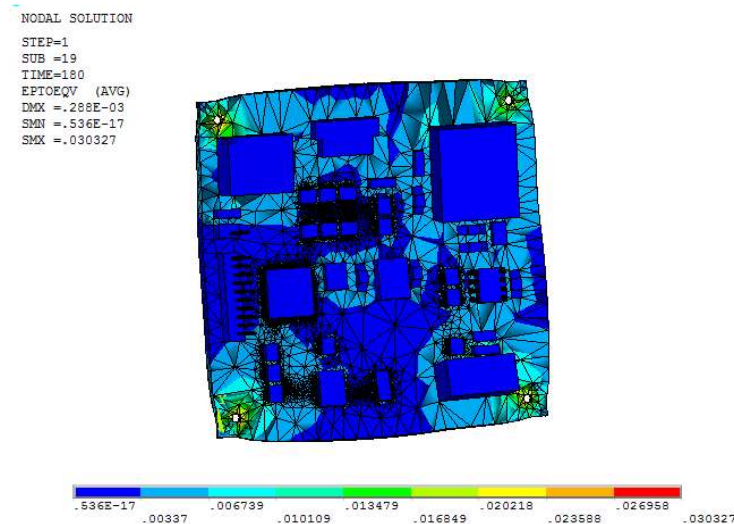


Figure 4. Thermal strain distribution at 180s

4. Conclusion

This paper calculates the thermal and structural analysis of the PCBA system by using the 3-D ANSYS package and the sequentially coupled physics analysis is adopted in thermal-structural analysis.

The result Fig.2 shows that the temperature of average distribution of main devices at 180S. Table 1 shows that the results of the simulation analysis. Fig.3 and Fig.4 show that Maximum thermal stress of MISES is about 36.8MPa and the thermal stress of the power connection jack and the capacitance in the middle are large.

The large thermal expansion coefficient difference with PCB plates results in obvious thermal stress. At the same time, due to the large thermal response, the capacitance is subject to large thermal deformation. Large thermal stress occurs near the capacitance, so, the weak components sensitive to thermal stress are determined through thermal-structural analysis. The results of thermal analysis are helpful to the optimizing overall arrangement design of PCBA system. The results provide beneficial references for solving the problem of thermal reliability of PCBA control system.

Acknowledgments

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