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Effect of Solder Joint Width to the Mechanical Aspect in Thermal Stress Analysis

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Abstract. The solder joint has a different dimension which depends on the component or package size. The thermal induced stress, strain and displacement is difficult to visualize due to small size during the component assembly process. Thus, this study is aimed to investigate those mechanical aspects via thermal stress analysis using finite element method. A model of surface mount capacitor was created in the simulation software. The influence of the different widths to the stress, strain and displacement were investigated. The simulation results revealed that the solder width significantly affects the stress, strain and displacement of the solder joint. The increment of the width decreases the strain and stress of the solder joint. The lowest stress and strain were found on the 3.1 mm of solder joint. Thus, the simulation results are expected to provide the understanding of mechanical aspects of solder joint in the thermal stress analysis.

1. Introduction

In the electronic assembly industry, surface mount technology (SMT) [1-2] is widely used in the assembly process. The surface mount component is assembled to the printed circuit board (PCB) via the solder paste material. The solidified solder material forms a solder joint or interconnector between the component and PCB. The interconnector provides the mechanical support, electrical connections to the component and also signal as well [3-6], which ensure the component could function properly in the entire electronic system. Therefore, the quality and reliability of the solder joint are important in the electronic assembly process.

The assessment of the solder joint reliability can be achieved via the thermal stress analysis at a fixed rate of temperature change or at the constant temperature [7]. The thermal analysis technique can be applied to assess the thermal endurance of PCB FR4 epoxy laminates [8] by ranging the temperatures range from 170 to 200 °C. Moreover, the thermal analysis can be performed by using simulation methods. Zhang and Bagnoli [9] used COMSOL solver to validate the methodology through different PCB layouts. They reported that Mesh density and the number of eigenvalues were the main influence factor to the simulation results.



In the simulation analysis, the accurate data input yields reliable results in the thermal stress simulation [10]. For example, the input data of coefficient of thermal expansion (CTE) is crucial, in which induced by the surrounding temperature variations during the reflow and wave soldering process [11-13]. As the extension of our previous work [14], the effect of the width to the mechanical aspects was considered in the current study. Moreover, finite element (FE) based software [15-19] was employed to create the model and perform the thermal stress analysis.

2. Methodology

Figure 1 illustrates the three dimensional model of capacitor with solder joint on the printed circuit board. The dimensions of the 3D model are 6.21 mm \times 3.1 mm (length \times width) for the capacitor. However, the solder joint width was ranging from 2.3 mm to 3.1 mm. The length of the solder joint is 3 mm. The dimensions of the PCB are 16 mm \times 8 mm \times 1.6 mm (length \times width \times height) [14]. In the simulation analysis, the interfacial copper layer between joint and the PCB was neglected.

A similar simulation setting and the material properties of different components were applied from our previous work [14]. Table 1 summarizes the value of the mechanical and thermal properties used in the current simulation, which are Young modulus, Poisson's ratio, thermal conductivity, density and coefficient of thermal expansion (CTE) of the 3D model. The 3D model was meshed by hexahedral element with 0.4 of mesh sizes and no error was found for the quality of the mesh.

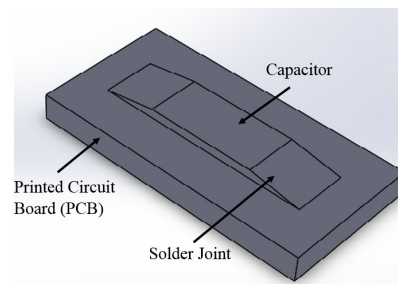


Figure 1. 3D model.

Table 1. Material properties for various components [20].

Component	Material	Young's Modulus (GPa)	Poisson's Ratio	CTE (pmm/°C)	Density (g/mm ³)	Thermal conductivity (W/mmK)
Capacitor	Aluminium	282.7	0.2222	6e-6	2.7e-3	205e-3
PCB	FR4 polyclad	27	0.17	14e-6	1.85e-3	0.81e-3
Solder	95.5Sn3.9Ag0.6Cu	43	0.3	23.2e-6	7.44e-3	60e-3

3. Results and Discussion

The simulation results in term of mechanical aspects (i.e., stress, strain and displacement) were studied. The relationship between the solder with and the mechanical aspects were analyzed and presented in this section. The width of solder joint used are 2.3 mm, 2.5 mm, 2.7 mm, 2.9 mm and 3.1 mm. Figure 2 shows the distribution of von Mises stress in the thermal stress analysis. It is noticed that the maximum stress was concentrated around the interfacial region between solder joint and capacitor. This situation may attribute by the variation of thermal properties between these components, which induce the thermal mismatch between the component and the solder joint. Hence, the expansion of solder joint lead to the stress generated around the interfacial region between solder joint and capacitor. The stress imposed on the solder joint may also cause by other phenomena such as mechanical load and during the fluid structure interaction [21].

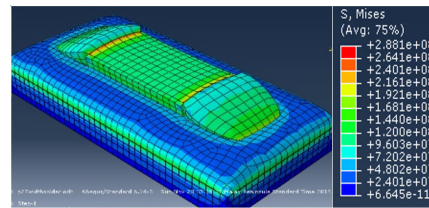


Figure 2. Von Mises stress distribution.

The correlation between the solder joint width and the mechanical aspects are presented in Figures 3-5. The results revealed that stress, strain and displacement of the solder joint exhibits in polynomial behavior to the solder width. The increment in solder width resulted in the decrement of the strain and stress as clearly shown in Figure 4 and Figure 5. This phenomenon may be attributed to the increase of the contact area of solder with PCB. The expansion of the solder joint is decreased due to the increasing of area or space. The expansion of the solder joint is not restricted in a confined space resulted the decreasing of strain and stress.

Figure 6 illustrates the correlation between the displacement and the solder width. The displacement of the solder joint increases gradually when the width increases from 2.3 mm to 3.1 mm. The increment of width simultaneously raises the volume of solder and lead to the greater volume expansion. Thus, the displacement increases when the width is increased. A similar phenomenon was also noticed in our previous work [14] in which the increase of solder length also contributes to the greater solder displacement. Therefore, the optimization of the process and design [22] of the electronic package is vital for the engineer to ensure the high reliability of the solder joint.

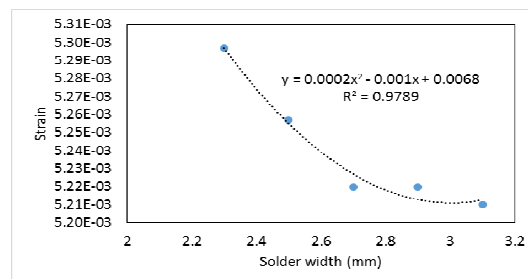


Figure 3. Maximum strain.

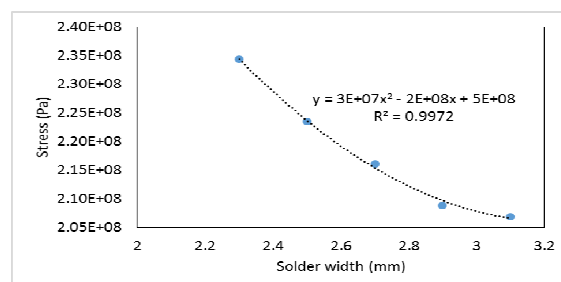


Figure 4. Maximum stress.

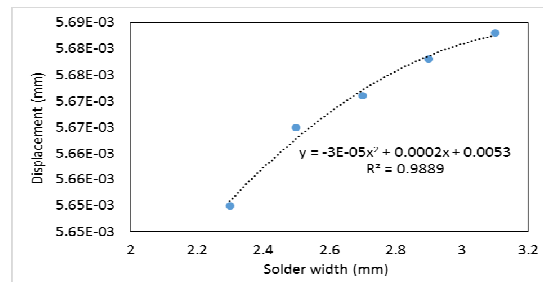


Figure 5. Maximum displacement.

4. Conclusion

The investigation of the solder joint width in the thermal stress analysis has been carried out via finite element based simulation. The influence of the solder width towards the mechanical aspects (i.e., stress, strain and displacement) has been studied. The distribution of the thermal induced stress of the component was visualized in three-dimensional model. The correlation between the width and the mechanical aspects was also discussed. The results revealed that solder width significantly affects the strain, stress and displacement in the polynomial behavior. Increase of solder width leads to the greater volume expansion and resulted in the increasing of displacement. Moreover, extremely high stress and displacement of the solder joint will lead to the unintended malfunction of the electronic component. Thus, the current results are expected to provide better understanding in term of mechanical aspects and the visualization of stress distribution in the 3D model. This study will be extended to focus on other parameters (e.g., PCB thickness and component size and shape) in the thermos-mechanical analysis.

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